1. ACCELERATOR

1.1 PELLETRON

1.1.1 Operational Summary

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Performance of 15 UD Pelletron accelerator was quite satisfactory from 1st April 2018 to 31st March 2019. Few problems were also encountered which were resolved properly. There was only one scheduled tank opening maintenance during the mentioned period. The details of the tank opening maintenance are mentioned in maintenance section. The operational summary of the accelerator from April 2018 to March 2019 is mentioned below.

Total No. of Chain Hours	=	7086 Hours
Total Beam utilization	=	5042 Hours
Machine breakdown	=	0244 Hours
Accelerator Conditioning	=	0500 Hours
Beam Change Time	=	0014 Hours
Tank opening maintenance	=	1054 Hours
Beam tuning time	=	0267 Hours
Experimental setup time	=	0094 Hours
Accelerator set up time after maintenance	=	0065 Hours

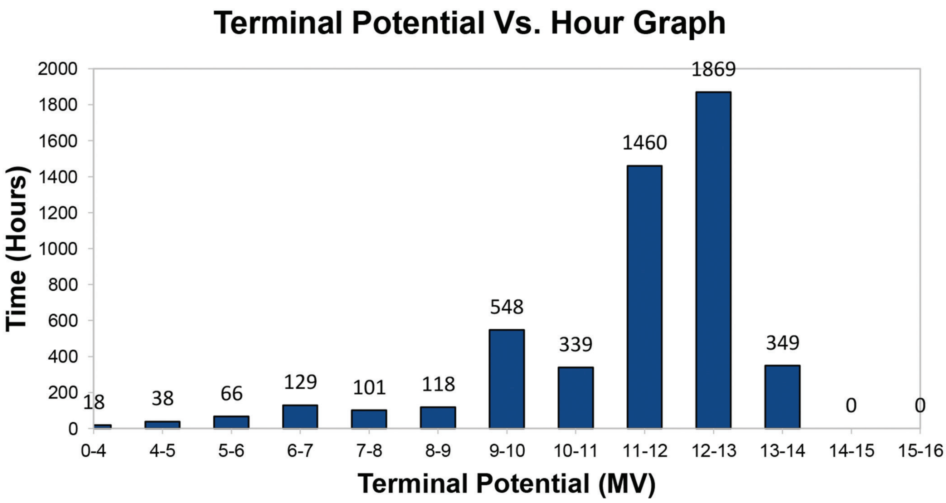

Figure 1.

Total number of 631 shifts were used for experiment during mentioned period, 130 shifts were for pulsed beam and 501 for DC beam. The machine up time for this period was 96.56% and the beam utilization was 71.15%. Figure 1 shows voltage distribution graph of Terminal Potential used for beam runs for the mentioned period. ^{28}Si, 9^+, 140 MeV dc beam at maximum terminal potential 13.99 MV and ^{7}Li, 3^+, 15 MeV dc beam at the minimum terminal potential of 3.7 MV were delivered to users. Maximum terminal voltage achieved during conditioning in this year was 15.3 MV. Figure 2 shows the Chain hours utilization for the mentioned period.

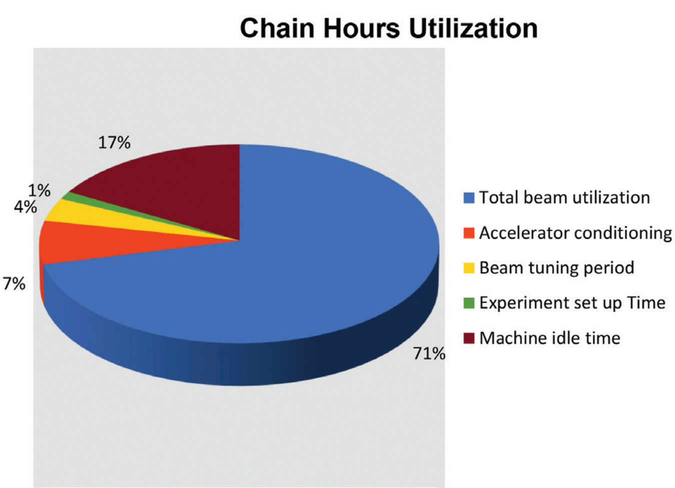

Figure 2.

Duration of beam run time in percentage, for different ions species, is shown in table 1.

Beam Delivered	Utilization (%age of total time)	Beam Delivered	Utilization (%age of total time)
^{6} Li	0.79%	^{35} Cl	0.09%
^{7} Li	7.41%	^{37} Cl	1.70%
^{9} Be	4.01%	^{48} Ti	1.21%
^{12} C	7.35%	^{56} Fe	1.22%
^{13} C	4.28%	^{58} Ni	4.45%
^{14} N	0.97%	^{63} Cu	0.31%
^{16} O	14.41%	^{79} Br	0.14%
^{18} O	13.87%	^{107} Ag	11.06%
^{19} F	3.66%	^{109} Ag	0.45%
^{28} Si	12.44%	^{197}Au	6.81%
^{32} S	3.36%		

Pi- chart in figure 3 shows the distribution of delivered beam species during beam run from 1st April 2018 to 31st March 2019.

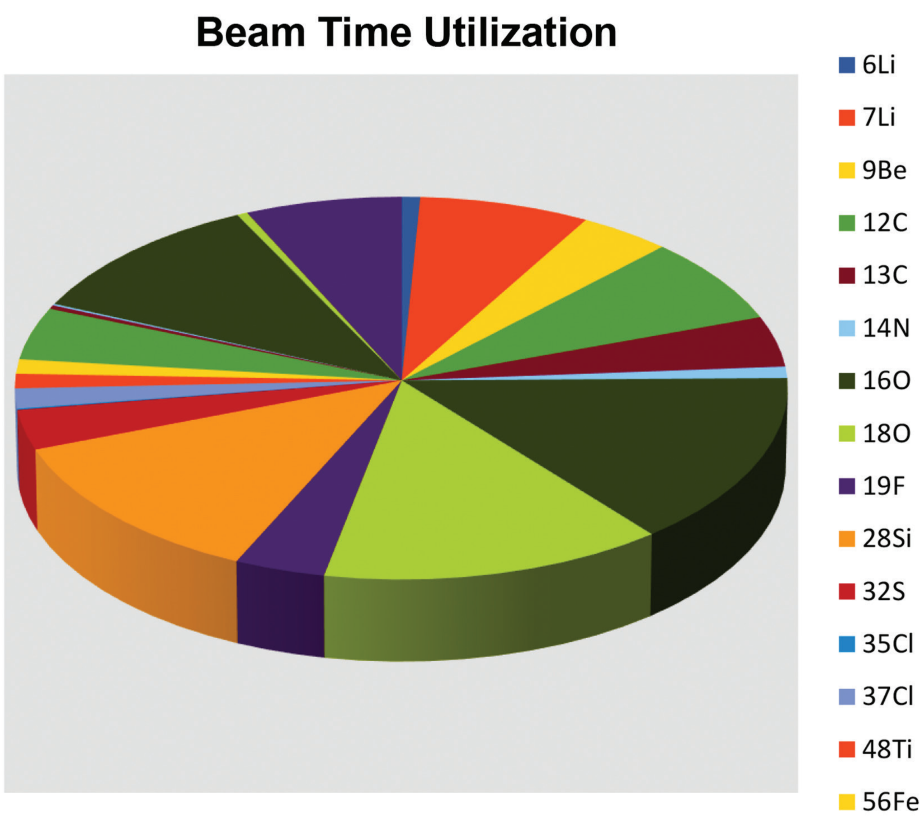

Figure 3.

1.1.2 Maintenance and Development Activities

There was only one scheduled tank opening maintenance. Detail of this maintenance is mentioned below.

Tank opening maintenance (scheduled)

There was only one scheduled tank opening maintenance in this academic year. 15 UD Pelletron was operated successfully for the users' experiment up to 30th July 2018. Thereafter, it was taken for scheduled maintenance from 1st August 2018 to 15th September 2018.

1) Jobs before tank opening

a) Testing of charging currents of both the charging chains

Condition of both the charging chains was accessed just before maintenance. Terminal of 15 UD was shorted to ground by using shorting rods. Both the charging chains were operated and their charging currents were observed at different Charging Power Supply (CPS) values. It was observed that current carrying capacity of chain #1 is better than chain #2 at a given CPS value. Charging chain #1 was able to carry ~51 mA at the CPS of 22 kV and its current started fluctuating at CPS values beyond 22 kV. Whereas, charging chain #2 was able to carry ~46 mA at the CPS of 22 kV and ~68 mA at the CPS of 32 kV. Charging current of chain #2 started fluctuating at CPS values beyond 32 kV. Fluctuation in charging chain #1 was higher as compared to chain #2.

b) Dew point measurement of SF_6 gas

Dew point of SF_6gas, stored inside Pelletron Accelerator Tank (PAT) was measured and found to be ~-27.5 deg C.

c) Testing of Earthquake RAMs (EQ RAMs)

The functioning of EQ RAMs was tested before tank opening at actual conditions. The EQ RAMs were pressurized at ~260 psi with SF_6 gas. Both the chain motors, both the rotating shafts and blower motor were put ON. TP was set equal to 12.023 MV at CPS = 9.6 kV with corona probe in for TP stabilization in AUTO / GVM mode. The earth quake sensor box, in control room, was hammered very lightly, with a mallet, to generate the effect of earth quake. As soon as it was hammered, the EQ sensor generated signal and EQ RAMs got fired and RAMs traveled towards terminal. A tank spark was generated and both the chains and both rotating shafts were tripped off. SF_6 gas pressure in EQ RAMs dropped down to ~230 psi. The EQ sensor was then reset from control room and EQ RAMs were retracted. After retraction of RAMs both the chains and both the rotating shafts were put ON to confirm the retraction of EQ RAMs. This test confirms the satisfactory working of EQ RAMs.

Major jobs performed during scheduled tank opening maintenance:

1. Charging system maintenance

Terminal was grounded, so that terminal should not accumulate any charge if chains are running. Condition of both the charging systems was checked. Total six idler wheels were replaced for charging system #1. Lots of vibrations were noticed in chain #1. After proper investigation, it was found that chain #1 got elongated, hence one pellet of chain #1 was cut. All the idler wheels of charging system #1 were aligned and its counter weight was adjusted for proper tension on chain #1.Both the chains ran and condition of all idler wheels for both the charging systems was checked in running condition which was satisfactory. Condition of nylon links for both the charging chains was inspected also for cracks and no crack was found. Performance of both the charging systems was checked electrically at different CPS from 2 kV to 7 kV and it was satisfactory. Both the chains were cleaned. Both the charging systems were kept ON for ten hours overnights to check its mechanical performance which was satisfactory. All the nuts and bolts for both the charging systems, in terminal area and at tank bottom, were checked and tightened, where required. Semiconducting rim of all the pulleys of both the charging systems were oiled with TP oil to reduce the friction between pulley and chain. Pillow blocks and chain motors of both the charging systems were properly greased. The ground connection of terminal was disconnected. This completed the charging system maintenance.

2. Maintenance of Rotating parts inside accelerator tank

Thorough maintenance of all the rotating parts, such as charging chain motors, rotating shaft motors, separator box assemblies for rotating shafts and blower motor was done. Bearings of total number of twenty two separator boxes were replaced, ten in low energy side and twelve in high energy side. Bearings of these assemblies were replaced with new ones. All the repaired separator box assemblies were installed back and aligned after maintenance. In all five tank motors (2 chain motors, 2 rotating shaft motors and a blower motor) were also greased properly.

3. Stripper foil loading in terminal

Fresh stripper foils were loaded in terminal; 154 stripper foils of IUAC make and 15 Diamond Like Carbon (DLC) type (micrometer make) foils.

4. Repairing of Column Support Post (CSP) gaps

To ensure that the condition of all CSP gaps is good, they were checked thoroughly. This is important for stable operation of tandem accelerator. If condition of even a single CSP gap or accelerating tube gap, is bad, machine cannot handle the rated high voltage and field will collapse. This may also lead to instability in beam.

Multiple vertical cracks were observed across gap #11 in unit #22 and its resistance was measured to be ~3.5 G ohms. This gap was shorted. Now, the total number of 36 CSP gaps have been shorted; 17 in LES and 19 in HES.

5. Hoop Screws maintenance

Equipotential rings, also known as Hoops, are mounted on every accelerating units of tandem accelerator and are responsible of proper field distribution. Hoop screws are the screws which hold the Hoops at the mounting position on Column Support Posts. Resistance between hoop screw and equi-potential rings ideally should be zero. But this resistance value varies from few ohms to Mega ohms and even open due to deposition of by-products of SF_6 gas.

Resistance measurement between Hoop screws and equi-potential rings was done for 14 units. The Hoop screw which shows more than 1 kilo ohm value, were changed.

6. Corona probe maintenance

The condition of all seven corona probe needles was good. Therefore, none of the corona needles were replaced.

7. Vacuum read problem for IP T-2 pump

There was no vacuum read from IP T-2. After proper investigation, it was found that a 6 channel ORA card in LL box at tank bottom, was faulty. This card was replaced to solve the problem.

8. Movement problem in Foil Stripper in HEDS

FS D2-1 was moving in INC mode but not in DEC mode. A dry solder point was located in the relay bases. Re-soldering of the bases of relays was carried out. This solved the problem and FS D2-1 started working in both INC and DEC mode.

Other maintenance outside Pelletron Accelerator tank

1. Maintenance of Vacuum related components

Routine maintenance of all ion pumps and sublimator pumps along with their controllers was done and required repair work was done where ever required.

2. Maintenance of different devices

The routine checkup and breakdown maintenance of different devices, such as Beam Line Valves (BLVs), Faraday Cup controller, a power supply, CAMAC control system etc., was also done.

1.1.3 Ion Source Activities

Operation

The operation and ion beam delivery of MC-SNIC ion source has been excellent during April 2018 to March 2019. Routinely, energized ion beam of various ion species in the energy range, 130 to 230 keV were extracted from the ion source. The ion source ran to its high capacity to provide pulsed ion beam. Other than routinely delivered ion beam, various enriched isotope ion beam, ^{6}Li, ^{13}C, ^{18}O and ^{37}Cl were produced. In regular interval, varieties of cathode samples were prepared as per users' requirement and loaded to the cathode wheel as and when required.

Maintenance

1. Preventive Maintenances

The source was opened in the month of September 2018 for routine maintenance. All the electrical connections of ion source were removed and the source was vented. The cesium was kept in Argon environment. The source was dismantled and all of its parts were cleaned thoroughly. The source was assembled, aligned and installed back after cleaning. New cesium was not loaded, rather we continued with the old cesium.

Apart from routine maintenance work a major maintenance work to replace the gate valve was also taken up. The gate valve is extensively used during every cathode loading process. The purpose of the valve is to isolate the cesium from the air This valve developed a through leak and due to this failure the cesium was contaminating. Therefore, this valve was replaced by new valve.

2. *Breakdown Maintenances*

During this year the MC-SNICS was opened once for break down maintenance work in the month of April 2018. The source was highly contaminated by the over flow of cesium. The Einzel lens assembly was unable to hold any potential and the ceramic surface got shorted from inside. Einzel lens focus power supply also went bad. The MC-SNICS source was vented with argon and opened. It was noticed that the ceramic studs holding the immersion lens had a layer of cesium on the surface and the Ionizer was also shorted. It was observed that whole source body was full of cesium. So all the ceramic parts were replaced with the new spares. The source body and the other components were cleaned properly. The source was assembled back and aligned. The Einzel lens assembly and ionizer were replaced with the new one. The source was installed back on the HV deck and new fresh Cesium was loaded. The cathode wheel was loaded with fresh cathodes and source was tested for regular operation. The damaged focus power supply was also repaired later.

Following breakdown maintenance related to electronics of ion source (MC-SNICS) was also carried out during the mentioned period:

1) Extractor power supply was not operating properly and beam could not be tuned properly. Power supply was replaced and repaired later.
2) During one of the user beam run, there was no beam current from the ion source. Connection from cathode power supply output to cathode broke from cathode side. This connection was restored to get the beam from ion source.
3) All the read back parameters from ion source were fluctuating due to failure of -15 Vdc bias supply in the LL box kept at ground potential. -15 Vdc was restored back to take care of the fluctuations.
4) Read back of HV power supply was fluctuating from -6 kV to -206 kV but the beam from ion source was stable. Investigated that temperature in ion source room was high due to problem in dehumidifier. The problem was taken care by placing an external cooling fan and later the dehumidifier was repaired. Now temperature is better than 25 deg. C and RH is better than 45%.

3. Developmental activities

Guide Rail Assembly for ion source

A development work related to the mounting of MC-SNICS source was also carried out. During a routine run, it was noticed that beam was getting steered in both X and Y axes in BPM #1 profile as and when immersion lens value was changed. This resulted due to misalignment in source mounting, which results in beam extraction at an angle from the source. A new mounting arrangement, with proper alignment, was developed and installed in ion source HV deck. The ion source, after maintenance, installed back by using this new mounting arrangement to ensure its proper alignment. This solved the steering problem of beam.

Thorough cleaning of HV deck, multiplier stack and filter stack of HV power supply was also carried out. Apart from this, Conditioning of HV deck was also done.

1.1.4 Beam Pulsing System

Operation

130 shifts of beam time was used for pulsed beam runs using Multi Harmonic Buncher (MHB) along with low energy chopper. Traveling Wave Deflector (TWD) was also used whenever different repetition rates of pulsed beam, other than 250 ns, is required. All the pulsed beams, were utilized by users to perform their experiments in different experimental lines. All 130 shiftss were utilized using Pelletron only and the beams bunched were ^{12}C, ^{13}C, ^{16}O, ^{18}O and ^{35}Cl.

There was no beam run using LINAC facility during the mentioned period.

All the pulsed beam runs were quite stable.

Maintenance

a) Chopper maintenance

Routine maintenance of chopper was carried out. Tuning of output stage of 100W, 4 MHz. With 50 Ω pure resistive dummy load was checked which was satisfactory. The output of this amplifier was then disconnected from dummy load and connected to tank circuit of chopper. Chopper tank circuit was then tuned for maximum power transfer from chopper amplifier. The chopper tank circuit could be tuned to get maximum forward power of ~20 W with reflected power of ~0.5 W. The chopper amplifier was kept ON for two days and its stability was satisfactory.

b) Traveling Wave Deflector (TWD) maintenance

In routine maintenance of TWD, all the control electronics and switching amplifier electronics were checked. The performance of TWD electronics was satisfactory.

During a beam run in January 2019, TWD stopped working. Plate voltage to tetrode valve got tripped off due to failure of 4^{th} channel. Problem was the failure of its driver circuit. The driver circuit was repaired to solve the problem. Thereafter, TWD worked satisfactorily.

1.1.5 Low Energy Negative Ion Implanter Facility

1. Operation

The operational status and ion beam delivery of the implanter facility had been excellent during the academic year (2018-2019). About 30 users from different colleges, universities and institutes availed the beam time from April, 2018 to March, 2019. Altogether, there were 31 runs. The sanctioned beam times up to AUC 65 as well as few beam times approved by Director, IUAC, were being successfully performed. The particulars about the implantation experiment performed during this period are given below:

1. No. of users: 30
2. Number of beam run: 31
3. Total time of machine run other than beam on the target = 320hrs
4. Total number of shifts utilized/beam on the target: 110
5. Total number of samples implanted: 1097
6. Ion fluencies used: 1x1012 to 5x1017 ions/cm2
7. Ion species utilized: ^{7}Li, ^{11}B, ^{12}C, ^{16}O, $^{24}C_2$, ^{27}Al, ^{28}Si, ^{31}P, ^{32}S, ^{40}MgO, ^{48}Ti, ^{56}Fe, Ge, ^{58}Ni, ^{59}Co, ^{63}Cu, ^{107}Ag, ^{197}Au
8. Energy range utilized : 20 to 200 KeV

2. Maintenance and development activities

The implanter accelerator system had a smooth run except for few breakdowns in control system and ion source injector systems. However, in regular interval, the operation had to stop for cathode sample loadings as well as for preventive maintenances. The ion source had run smoothly for almost one and half year without any maintenance. Therefore, in the month of May, 2018, after performing the break down maintenance, the preventive maintenance was carried out. It was mainly for cleaning three components of injector system i.e. a) ion source assembly, b) Einzel lens assembly and c) Accelerating column (General Purpose Accelerating tubes).

In mid-April, 2018, ion source failed to function. The problem was investigated and solved as mentioned below.

1. The frequent failure of DAC in IMAC placed on HV deck of Negative Ion Implanter during HV spark or glitch. Source could not be operated. Grounding connection related HV deck was modified. After proper grounding and grounding modification work, DAC is working fine.
2. Output voltage of Extractor power supply was ~130Vdc even if control voltage from control console is zero. Problem investigated and found that actual voltage at the control input of extractor power supply was 0.065Vdc with zero control input from "Control Console" which make the power supply output ~130 Vdc. The analog ground of DAC was connected to chassis ground to solve the problem.
3. Whenever the HV deck voltage was increased to 200kV, the extractor power supply read back increases to ~5.5 kV without any control voltage input to extractor power supply. Value of the resistor, connected

between extractor power supply and ground, got increased. This resistance was replaced to solve the problem.

4. Relative Humidity (RH) of high voltage room raised up to 86% while its room temperature was lying low around 22^{0}C. This caused discharge paths all over the insulation surfaces of accelerating tubes, lenses and Teflon insulation gaps that isolate ion source assembly, Einzel lens and GP tubes from High Voltage deck. New insulation gaps were designed and fabricated in IUAC workshop. They replaced the old ones without disturbing alignment of beam line. Higher load current, due to high RH value, was observed from deck HV supply. The RH value is now controlled to ~54% to solve the problem.

5. There was another failure of CAMAC control system for the beam line. it was rectified by replacing the damaged card.

From July, 2018 onwards, energized ion beams were delivered to users for their experiment. The radiation monitor was replaced with a new calibrated one. Apart from operation and helping users for their experiment, efforts were made to develop new beams as per users' request.

1.1.6 Utilization of Beam Runs using 15 UD Pelletron Accelerator from 1st April 2018 to 31st March 2019

The utilization of beam time by different users, using facility at IUAC, New Delhi is mentioned below. Field wise utilization and user wise utilization of beam time are shown in figure 4 and figure 5 respectively. List of users from different universities, colleges, IITs etc. are tabulated in table 2.

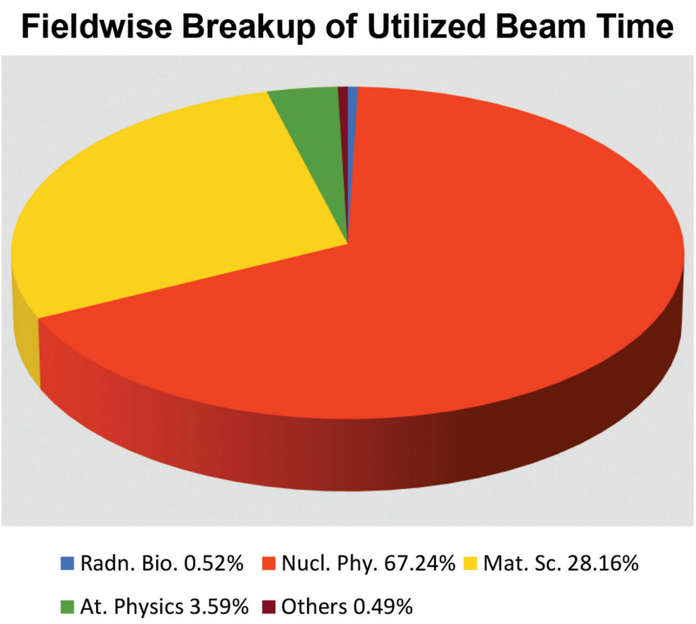

Figure 4.

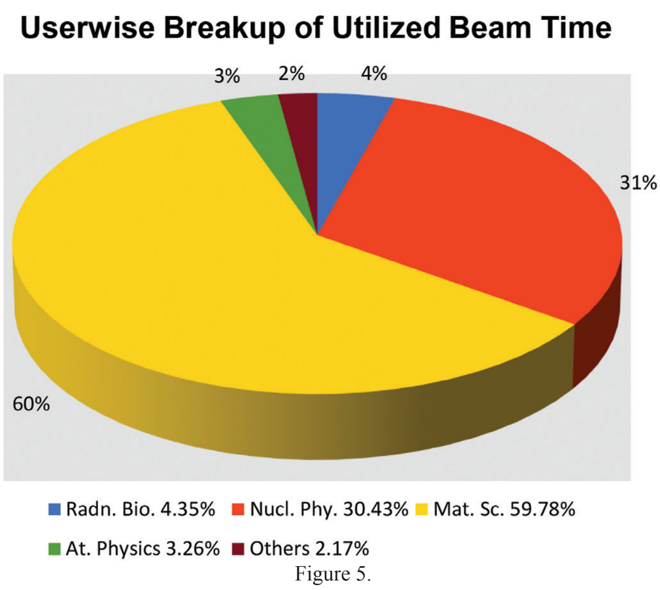

Figure 5.

Table 2. User List : April 2018 to March 2019

Sr. No.	University / Institute / College	Shift Utilized
1.	Aligarh Muslim University	39
2.	Amity University, Noida	3
3.	Andhra University	14
4.	Banaras Hindu University, Varanasi	48
5.	BARC, Mumbai	4
6.	BCAS & C Kalyan	3
7.	Bharathiar University	3
8.	Central University of Jharkhand, Ranchi	20
9.	Central University of Kerala	12
10.	Central University of Punjab, Bhatinda	1
11.	Central University of Rajasthan	9
12.	DA Vishwavidyalaya, Indore	6
13.	DAE CSR, Kolkata	32
14.	DAV College, Amritsar	3
15.	Doon University, Dehradun	9
16.	Dr. B.A.M University, Aurangabad	5
17.	Dr. B.A.R.N.I.T, Jalandhar	2
18.	G.B.P.U.A.T, Pant Nagar	3
19.	Gauhati University	15
20.	GGSI University, New Delhi	10
21.	GGD University, Bilaspur	4
22.	GNDU Amritsar	3
23.	Gautam Buddha University, Greater Noida	1
24.	Gujrat University, Ahmedabad	3
25.	HP University Shimla	20
26.	IGCAR, Kalpakkam	3
27.	IISER, Mohali	1
28.	IIT, Roorkee	8
29.	IIT, Ropar	18
30.	IIT, Jodhpur	9
31.	IIT, Kharagpur	6
32.	ISRO, Bengaluru	11
33.	IUAC (Student), New Delhi	3
34.	IUAC, New Delhi	42
35.	Jamia Milia Islamia, New Delhi	1
36.	JNU, New Delhi	1
37.	KA&S College, Coimbatore	2
38.	Kalindi College, New Delhi	21
39.	Kanya Mahavidyalaya, Punjab	3
40.	Karnataka University, Dharwad	16

41.	KIIT University, Bhubaneswar	2
42.	Kyoto University, Japan	3
43.	M.S.U. of Baroda, Vadodara	19
44.	MNIT Jaipur	11
45.	Nirmal University, Gujrat	4
46.	NIT, Srinagar	1
47.	Panjab University, Chandigarh	25
48.	RTMN University, Maharashtra	3
49.	Shiv Nadar University, Greater Noida	1
50.	Sikkim University	3
51.	SINP, Kolkata	21
52.	SLIET, Longowal	6
53.	UCEA, Tamil Nadu	3
54.	Kalyani University, Kalyani	21
55.	University of Calicut, Kerala	13
56.	Delhi University, Delhi	29
57.	University of Hyderabad	6
58.	University of Mysore	3
59.	Tripura University	3
60.	Visva Bharti Shantiniketan	36
61.	VTU, Mangaluru	1

1.2 LINAC

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1.2.1 Status of the Superconducting Linac

The superconducting (SC) linac working as the energy booster for the Pelletron accelerator consists of five cryostats containing twenty seven quarter wave resonators. Twenty four resonators are used to accelerate the ion beam and the remaing three are responsible for longitudinal focussing or defocussing (only for Rebuncher) of the beam. As previously reported there was an extened beam run of linac for user experiments for more than 5 months duration during year 2017-18. During the beam acceleration, an energy gain of about 9 MeV/q had been demonstrated. In order to achieve higher energy gain, steps were taken subsequently. As the performance of most of the resonators in Linac-III cryostat was found to be less than the desired value, steps were taken to improve the performance of resonators in Linac III. Based on the past history of the resonators, four resonators out of eight were electropolished and all the resonators were rinsed with high pressure (~80 bar) 18 MΩ-cm deionized water along with their couplers, slow tuner bellows and pickups inside class-100 clean room. The resonators were also assembled in the same clean room before loading them in the cryostat inside a class-5000 clean room. An Offline test of Linac III was done to evaluate the performance of the resonators post the surface treatment. Significant improvement in the performance of all the resonators except one was observed as compared to the last linac operation. During the beam acceleration in 2017-18, the time bunching of the beam at the user's scattering chamber was supposed to be accomplished by the two resonators of the re-buncher (RB). As reported in last year's annual report, this was completely avoided for the extensive use of optimum phase focusing (OPF), for each and every scheduled experiment. The RB resonators are now planned to be used in accelerating mode and phase optimization for the same is being worked out with optimum phase focusing (OPF) using an in house developed program. Three cases have been studied where OPF has been applied along with RB as accelerating QWRs. The ΔE at LINAC exit, after RB and the Δt at NAND experimental area for the three cases is tabulated in table1 below. The results will be verified experimentally during linac oper`ation.

Table 1: OPF case studies with RB as accelerating QWRs

Case	ΔE @ LINAC exit	ΔE @ RB exit	Δt @ NAND area
Case1: OPF of all 26 QWRs optimized @ NAND	~ 0.75 MeV	~ 0.2 MeV	~ 0.430 ns
Case2: OPF of 24 QWRs optimized @ RB + OPF of 2 RB QWRs optimized @ NAND	~ 0.6 MeV	~ 0.68 MeV	~ 0.360 ns
Case3: OPF of 24 QWRs optimized @ NAND + OPF of 2 RB QWRs optimized @ NAND	~ 0.325 MeV	~ 0.6 MeV	~ 0.190 ns

1.2.2 Developmental activities accomplished to Improve the Linac Operational Efficiency

A. Implementation of PWM based frequency tuning scheme for super-buncher and rebuncher.

The super buncher, Re-buncher and first accelerating module of linac use pneumatic helium gas operated tuners for phase locking of the resonators. The control scheme of the gas operated tuners of first linac module were improved with a pulse width modulation (PWM) based control mechanism and the same was successfully tested to phase lock all the resonators of linac 1 during last linac acceleration for more than five months. It can correct the slow drifts in frequency at a faster rate thereby making the resonators less prone from frequency unlocking and reducing the RF power requirement. Implementation of the PWM based tuner control mechanism on the resonators of the super buncher (SB) cryostat and re-buncher cryostat is completed this year for better operational efficiency. For both super-buncher and re-buncher, the mechanical assembly is similar to the linac cryostat 1 with two channels operating on each pot assembly. Two channel Helium gas flow system was tested with independent electronics modules (two channels). In Superbuncher set up the second channel has been kept as spare whereas an additional two channel spare assembly was made for rebuncher

B. Remote RF drive control for resonators during Linac operation

When the resonators produce high accelerating fields, especially at the time of high Power Pulse conditioning, access is often restricted due to the presence of X-rays. In order to avoid exposure to radiation during high power pulse conditioning, prototype remote movement of the drive couplers of the resonators were tested earlier along with software interface for pulse conditioning of the resonators from existing Pelletron-Linac control room. Dedicated electronic modules consisting of remote control system using incremental encoders for closed loop position control of the power couplers to couple power in to the superconducting resonators is developed. The electronics module control the stepper and monitors the exact coupler position. The actual position sensed by the encoder is calibrated and displayed on a local display. The system design uses a serial network type architecture to enable control of RF power coupler motors of the resonators with a serial networked backbone based on the RS485 standard to integrate 8 channel motor position control units. While the RS485 backbone is implemented with the help of unshielded twisted pair (UTP) wiring with proper end terminations, the coupler motor controllers act as the control nodes. The motor, constrained by the limit stoppers, rotates in response to commands sent by the local keypad. When one of the endpoint limits is reached, micro-switch based limit sensors get actuated, causing immediate stopping of the motor.

The system is responsible to control of the 27 RF power couplers from the control room. High Power RF conditioning of all the resonators of the three accelerating modules of the superconducting linac is planned from the control room. During the forthcoming operation of linac, the remote drive control mechanism will be extensively used for all the resonators of linac.

C. Dedicated Electronics module for Energy and time measurement of Linac beam.

Surface barrier detectors are routinely being used to measure the energy and timing in the Diagnostic box. The processing of the timing and energy signals from the pre amplifier are processed using various commercial nuclear electronics modules such as spectroscopy amplifiers, Timing filter Amplifier (TFA), Constant fraction discriminators (CFD), Gate and Delay generator (GDG), Time to Amplitude converter (TAC). In order to avoid using these expensive imported modules and to ease the requirement of interconnections among the modules, a dedicated module combining the specific requirements of energy and timing signals from pre amplifier is designed. The module takes energy and timing signal from the pre amplifier of the detector and gives analog output and strobe signal for pulse sensing ADC for digitization. The module is under the final stage of development and planned to be tested during linac operation.

1.2.3 Superconducting Niobium Resonators

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The construction of six spare quarter wave resonators (QWRs) and additional slow tuner bellows for the superconducting linac has progressed further. The two SSR1 resonators with their outer helium vessel installed, were sent to Fermilab. IUAC had attached the Nb-SS brazed transition rings on the SSR1 resonators prior to the installation of the helium vessel by BARC, Mumbai. One of the resonators that has performed exceedingly well has been installed in the SSR1 cryomodule for the PIP-2IT injector experiment. For carrying forward the studies on improving the accelerating gradient and quality factor in quarter wave resonators, a resonator that had been set aside due to its high resonance frequency, is being readied. The 2nd prototype low beta resonator is also being completed.

1.2.3.1 Construction of Spare QWRs and Slow Tuners for Linac

Construction of the six spare QWRs for the superconducting linac has progressed further. The QWRs and slow tuner bellows are being built as spares for the Linac as well as for conducting other offline development works. Several parts / sub-assemblies for the resonators, e.g. components for the drift tubes, transition flange assemblies and slow tuner bellows, have been completed. In figure1, several parts/assemblies are shown.

Figure 1: Clockwise from top-left: (i) niobium housings, (ii) end caps and upper caps, (iii) welded niobium leaves for the slow tuner bellows, (iv) transition flange assemblies.

1.2.3.2 SSR1 Single Spoke Resonators

The two SSR1 niobium single spoke resonators which had come back from Fermilab after the VTS tests for the installation of the outer helium vessel, were sent back to Fermilab after completing the work. IUAC had attached the Nb-SS brazed transition rings on the SSR1 resonators before the helium vessel was installed by BARC, Mumbai. In 2K tests of the dressed cavity in the spoke test cryostat (horizontal test stand) the first resonator S104 performed exceedingly well. In fact the performance of this resonator is one of the best among the resonators installed in the SSR1 cryomodule for the PIP-2IT injector experiment. In figure 2, the performance of SSR1 S104 at 2K is shown.

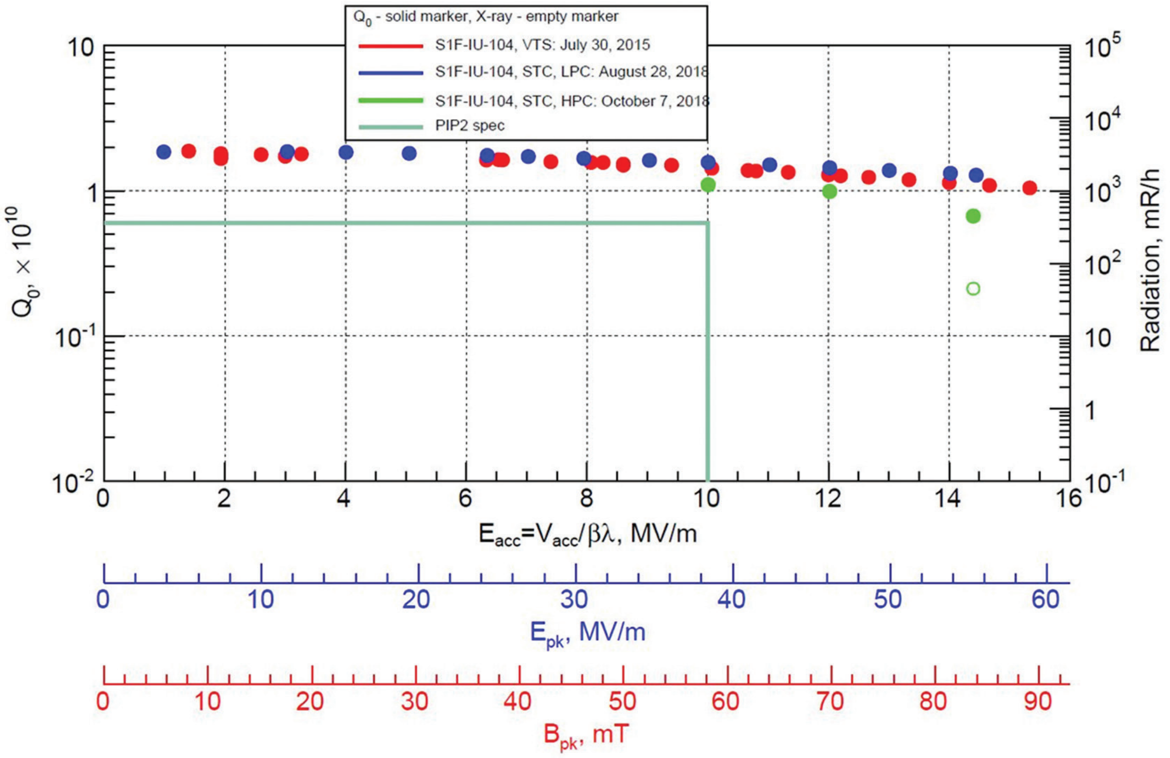

Figure 2: 2K Test Result of dressed SSR1 S104 single spoke resonator tested at Fermilab. The box shows the PIP-II design specification.

1.2.3.3 Reworking of QWR-I11

Systematic studies have been conducted to improve the achievable accelerating gradient and associated quality factor in QWRs using several different techniques [1]. In order to continue these studies, a QWR (QWR-I11) which had been kept aside due to its low resonance frequency, is now being completed. The resonator has been cut open and its central conductor has been shortened to the correct size to obtain the desired frequency. This resonator is now ready after the reworking, electropolishing and heat treatment, for the installation of the outer helium vessel. After completion, initially it will be tested for a baseline test (at 4K) before subjecting to further processing to study the improvement in its accelerating gradient and quality factor through various techniques which will include nitrogen doping and infusion.

1.2.3.4 Completion of 2nd Prototype Low Beta Resonator

The first prototype low beta resonator has performed exceedingly well; very easily achieving the design goal of 6 MV/m accelerating gradient at 4 W of RF Power. In order to validate the various processing techniques that have been systematically studied [1], performing the tests on a low beta resonator provides further credence to them. Some of the tests have been already applied. In order to expedite the turn-around time for processing and testing of various resonators, it is essential to have additional resonators available in hand. In view of this the 2nd low beta resonator is being completed. The resonator is ready for electropolishing which will be followed by heat treatment. Thereafter it will proceed for the installation of the outer helium vessel. We feel that the resonator will be available for cold tests in the next 3-4 months.

REFERENCE:

[1] A. Rai et al., accepted for publication in Superconductor Science and Technology, in press, https://doi.org/10.1088/1361-6668/ab2794

1.3 PARAS (1.7 MV PELLETRON ACCELERATOR AND RBS ENDSTATION)

1.3.1 Operation

The 1.7 MV Pelletron accelerator for Rutherford backscattering facility was in regular operation all year round. Total 2015 measurements of 73 users from 40 Universities/colleges/institutes were performed. Around 40 Publications and 10 conference proceedings came out of measurements carried out ustilizing the facility.

RBS, Channeling, Resonance RBS for Oxygen and Nitrogen energies were routinely performed. Elastic Recoil Detection Analysis (ERDA) to assess the hydrogen content in the sample was also performed for couple of users. RBS is one of the popular methods of ion beam analyses performed for different types of samples including thin films on substrates, free standing, carbon supported grown by different techniques such as thermal evaporation, RF sputtering, MBE and PLD. The ion implanted and irradiated single crystals, thin films and bulk samples are also characterized using RBS and Channeling. Ion channeling is very accurate method for probing defects caused by implantation.

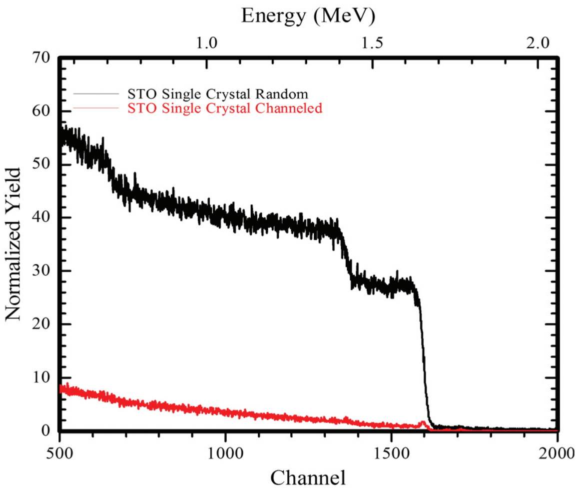

Fig 2A: RBS Random and Channeled spectra of STO single crystal with χ min = 3.45%

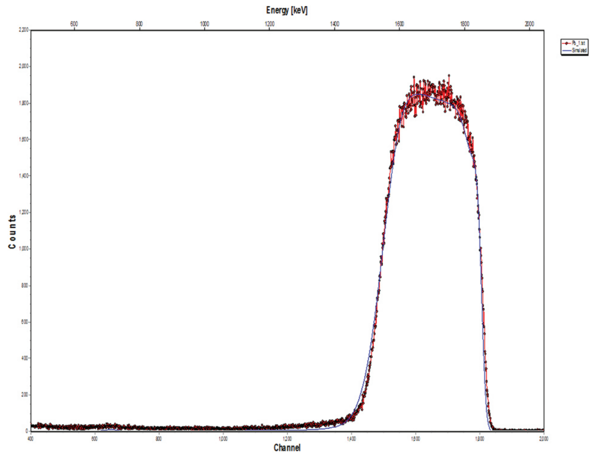

Fig 2B: RBS spectra of self-supported Pb target (red) deposited by thermal evaporation with simulation (Blue).

Resonance backscattering 16O(α,α)16O at 3.045 MeV, 14N(α,α) 14N at 3.69 Mev commonly referred Resonance RBS as has been used for oxygen and Nitrogen depth profiling in various thin oxide films, implanted and processed materials respectively.

ERDA setup at IUAC is suitable for hydrogen estimation up to depth 0.5–1µ. Measurements are performed with 2.7- 3.045 MeV alpha projectiles impinging over 75° to surface normal. Forward recoiled protons at round 30° are detected by detector with a stopper foil to stop scattered alpha particle.

1.3.2 Maintenance

1.3.2.1 Ion Source Maintenance

Ion source maintenance was performed during November 2018. The source got chocked due to deposition of Rubidium all around, preventing helium beam from coming out. The source was opened, cleaned and reassembled back. Rubidium was loaded in argon atmosphere. Two ampules of 5 grams each is loaded for smooth operation of source. It has been observed that, once loaded, the source runs for 700-800 hours. On conditioning the source for few hours, continuous and stable He- beam was achieved.

Interlock circuitry of ion source hanged because of malfunctioning of one of the 24 V power supply. A supply was installed with the help of Beam Transport Lab to solve the problem.

1.3.2.2 5SDH2 Pelletron Accelerator and Endstation Maintenance

No major maintenance of Pelletron accelerator was carried out. The accelerator operated smoothly with highest terminal potential around 1.2 MV. Control system of RBS endstation stopped working as one data file got corrupted. The new data file was generated and control system was made operational at the earliest.

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 is in operation since March 2015. The 500 kV accelerator is of tandem type and procured from National Electrostatic Corp. (NEC), USA. Carbon sample processing and graphitization are performed in a comprehensive graphitization laboratory and ^{10}Be and ^{26}Al samples are processed in a clean chemistry laboratory.

1.4.1.1 Graphitization Laboratory

Graphitization laboratory is equipped with all the equipment required for the sample pre-treatment and graphitization. Charcoal, wood, macrofossils, plant remains, sediment and carbonate samples (shells, foraminifera) are processed routinely in this laboratory. Different pre-treatment methods, depending upon the type of samples, are followed. This laboratory is equipped with three Automated Graphitization Equipment (AGE) coupled with elemental analysers for the graphitization of organic samples. Out of these three AGE, one AGE is also coupled with carbonate handling system (CHS) for the graphitization of carbonate samples. During April 2018-March, 2019, about 850 samples have been pre-treated and graphitized by 25 users from different universities and institutes for their research work.

1.4.1.2 Graphitization of small size samples using AGE

AGE is utilized to graphitize samples having various sample sizes which produces 200 µg to 1000 µg of CO_2. This sample size range covers most of the radiocarbon dating applications. However, there are certain applications where even smaller sample sizes are available to graphitize. For example: radiocarbon measurement of particulate matter, DNA, compound specific radiocarbon dating etc. Therefore, we tried to graphitize OXII, IAEA radiocarbon standards and Ph blank samples in different sizes to produce 20-200 µg of CO_2 using AGE. To observe the effect of temperature, we have also performed graphitization reaction for these samples at different graphitization temperatures, 450, 500, 550, 580 and 600 °C. To observe the effect of size of reaction tube, we have performed graphitization of these small samples in two different tubes having length 8 cm (tube used for regular size samples) and 5 cm. Tube used for regular size samples have been cut down to 5 cm length.

We have found in this study that samples having size up to 60 µg can be graphitized using AGE. We have found best results at 580 °C temperature using reaction tube having length 8 cm. But graphitization yield for theses sample was very less, so current observed in ion source was also less in comparison to regular size samples. Also higher background values were observed for small size samples. All these shortfalls can be improved if we can improve vacuum in graphitization system and water absorption during graphitization reaction.

1.4.1.3 Use of iron nano size powder as a catalyst in graphitization reaction

Iron powder is used as a catalyst in graphitization reaction. Particle size of iron powder used for this purpose is in micron range. What happen if we use iron nano powder for this purpose? To investigate this, we first synthesized iron oxide nano powder using green route. We dissolved iron chloride in water and then green tea extract was mixed into this solution. A black color solution was obtained and it was centrifuged and resultant iron oxide was freeze dried. XRD and SEM analysis confirmed that the obtained powder was Iron oxide with particle size in 40 – 50 nm range. Further, Iron oxide nano powder was conditioned in AGE by treating it with hydrogen gas. Conditioned Iron oxide was also analyzed with XRD and SEM and it was found that the iron oxide nano powder was converted into iron nano powder. OXII and Ph blank samples were prepared with AGE system using iron nano powder as catalyst.

In comparison to normal (micron size) iron powder, following three points were observed in graphitization with iron nano powder:

- Longer reaction time (150 minutes) is needed for complete graphitization in comparison to normal iron powder (120 Min.).
- Lower background values.
- Lesser amount (0.8 – 1 mg) of iron powder is required in comparison to normal size iron powder (4-5mg).

1.4.1.4 Training to the Birbal Sahni Institute of Palaeosciences (BSIP) Radiocarbon laboratory staff

BSIP, Lucknow has procured automated graphitization equipment (AGE) and Carbonate handling system (CHS) for radiocarbon AMS sample preparation. BSIP radiocarbon laboratory staff was trained by our group in the field of pretreatment and graphitization of samples using above two instruments. Total 35 samples (some of them were graphitized in BSIP lab) have been prepared and measured in this exercise.

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

After renovation activities this laboratory was used to prepare 160 ^{10}Be and 31 ^{26}Al samples by 5 different users.

Beryllium was extracted from 130 sediment samples by following users:

- Sediment samples from Mahanadi Basin, Bay of Bengal – 35 samples (NIO, Goa)
- Antarctic & Arctic Lakes, -65 samples (Goa Univ)
- Sediment samples from Chillika and Anshupa lake – 30 samples (IIT Roorkee)

Beryllium and aluminium were extracted from 31 quartize samples by following users:

- Quartz samples from Kashmir Valley – 15 samples (Kashmir University).
- Quartzite rock samples from Sikkim – 16 samples (BSIP/BHU).

Twenty standard samples were also prepared from SRM 4325 (treated for Boron reduction) and SRM, 3105a.

1.4.1.6 XCAMS facility

The AMS system at IUAC is designated as XCAMS i.e. Compact ^{14}C Accelerator Mass Spectrometer eXtended for ^{10}Be and ^{26}Al. This system is routinely utilized for the measurement of ^{14}C, ^{10}Be and ^{26}Al. Total 1100 graphite (^{14}C) samples and 44 ^{10}Be samples have been measured this year. 37 users from different institutes have been utilized this facility for their research work.

Maintenance

Following maintenance activities were carried out in this facility.

- 134 MC SNICS source was opened for routine maintenance in February and October. This source was also opened in April for breakdown maintenance and Ionizer was replaced.
- 40 MC SNICS was opened for routine maintenance in July. Ionizer and other parts were cleaned. This source was also opened in March (2019) for breakdown maintenance. The reason for breakdown maintenance was that the immersion lens voltage was following the cathode voltage. Source was opened, cleaned, re-assembled and brought back to operation.
- Accelerator tank was opened for breakdown maintenance in March. It was found that the varistor is faulty in the circuit used for providing power to rotating shaft of Pelletron. Same problem was also occurred in October but problem was fixed without opening the tank.
- Channel 2 of pixie was not working. However, channel 3 of pixie was empty and also working fine. Therefore, pre amplifier signal (dE2) was fed to channel 3. This new configuration was also updated in AccelNet software for smooth data collection.

1.4.2 National Geochronology facility

Deeksha Khandelwal, Umapathy G R, R. Sharma, Soumya Prakash Dhal, Chinmaya Maharana, Pankaj Kumar, S. Ojha, S. Gargari, R. Joshi, S. Chopra and D. Kanjilal

The objective of the project is to develop a comprehensive Geochronology facility at IUAC that will permit measurement of quality isotopic data for Geochronological purposes including relevant characterization at the highest international level. The dedicated geochronology facility at IUAC will enable researchers from Indian Universities and research institutes to study different aspects related to Earth Sciences. The proposed geochronology facility will enhance the research capabilities in the country with the following objectives:

- Carrying out various research studies in the field of climate change, palaeo-climate studies, global carbon cycle, oceanographic parameters, Antarctica research programs, archaeology, biomedicine and history of art etc.

- Capacity building: Initiation of new PhD programs using the facility for universities and research institutions.
- Generating geochronological data that shall be of interest to Earth Scientists, which require precise geochronology.

Following instrumentation have been commissioned and being utilized under this project:

Quadrupole- Inductively coupled plasma mass spectrometry (Q-ICPMS)

Q-ICPMS (Model: iCAPQ) procured from Thermo Fisher Scientific has been operational since early 2018. Fig 1 shows the Q-ICPMS installed with auto-sampler. This has been used for the trace element and rare earth element (REE) analysis of the water samples and digested rock and sediment samples. The samples are introduced by the peristaltic pump to the nebulizer where the fine aerosols of the sample are generated. Argon plasma is ignited in the ICP torch by coupling the RF energy with argon gas. The sample aerosol is introduced to the plasma and the positive ions of the components of the aerosol are formed. These positive ions are passed to the quadrupole which acts as a mass filter and selects a particular m/z at one time. Ions of a given m/z are counted by the detector which gives the measurable electronic signal corresponding to the number of incident ions. The detector system is of secondary electron multiplier (SEM) type, in which the ions incident on the first dynode of the detector produces electrons. These electrons strike the surface of the second dynode and more electrons are produced. The signal is amplified until a measurable signal is detected. Q-ICPMS provides a dynamic working range from ppb to percent. An auto sampler procured from Teledyne CETAC Technologies has been coupled to the Q-ICPMS. At a time 180 samples can be loaded for the sequential measurement.

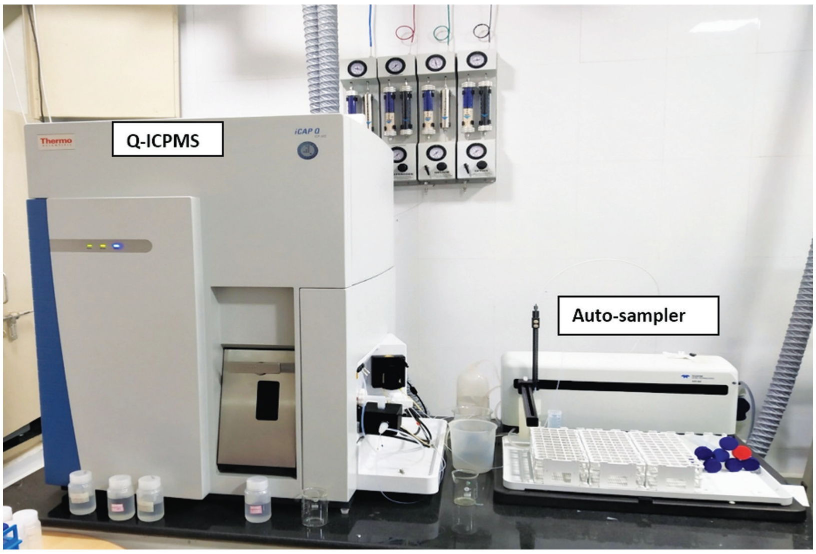

Fig 1: Q-ICPMS installed with Auto-sampler

Q-ICPMS has regularly been used by the users from several universities and institutions for determining the trace and REE metal concentration. During April-2018 to March-2019, trace metal and rare earth element (REE) analysis of 560 samples of 7 users from 4 different universities has been done using Q-ICPMS. Brief scientific motivation of the studies performed are the reconstruction of the paleo-climate and paleo-environment, to understand the controls on ground water geochemistry (Central University of Punjab, Bhatinda), to study the elemental mobilization process during granite weathering (JNU/IUAC), to assess ground water quality in the coastal region of Kerala (JNU), to reconstruct the quaternary climatic variability and sediment provenance of the little Rann of Kutch (MSU, Baroda/JNU), quantification of metals in aerosol collected from Agra region (DEI Agra) and concentration of heavy metals in soil and water samples from Chamba district of Himachal Pradesh to study their effects on the growth of the crops as well as the human health (LPU, Jalandhar).

Femto second laser ablated high resolution- inductively coupled plasma mass spectrometry (Fs-LA-HR-ICPMS)

HR-ICPMS (model: ELEMENT-XR) procured from Thermo Fisher Scientific is now operational. This ICPMS is equipped with the auto sampler and syringe driven inline dilution system procured from Teledyne CETAC

Technologies and ESI prepFAST respectively. Fig 2 shows the HR-ICPMS installed with laser, auto-sampler and auto-dilution system. The samples are introduced by the peristaltic pump to the nebulizer where the fine aerosols of the sample are generated. Argon plasma is ignited in the ICP torch by coupling the RF energy with argon gas. The sample aerosol is introduced to the plasma and the positive ions of the components of the aerosol are formed. The positive ions are passed through a high resolution magnetic sector. This magnet selects the ions based on the ME/q^2 of the incident ions. The detection system consists of a combination of dual mode secondary mass spectrometer (SEM) with a Faraday detector. HR-ICPMS has several advantages over Q-ICPMS. Magnetic sector field in place of quadrupole, removes most of the interferences. The high resolution of ELEMENT XR makes it suitable for the measurement of isotopic ratio measurement. Using the dual detection mode, the dynamic range is increased by three orders of magnitude and count rates of the order of 10^{12} cps can be handled. Element XR at IUAC has been interfaced with a Teledyne femto second laser. Nd:YAG (neodymium-doped yttrium aluminum garnet; Nd:$Y_3Al_5O_{12}$) is the crystal that has been used as a lasing medium in Teledyne laser. The system can be configured for 1028 nm, 257 nm or 206 nm wavelengths. U-Pb dating of different phases of minerals can be done with ELEMENT-XR.

Liquid solutions or solid samples (via laser ablation) can be analyzed with the help of ICPMS. The technique finds the application for trace element analysis and in the field of geology, environmental sciences, pharmaceuticals, food analysis, clinical, and forensic sciences.

Fig 2: HR-ICPMS installed with Femto-second laser, auto-sampler and auto-dilution system

Wave length Dispersive X-Ray fluorescence and X-Ray Diffraction:

X rays fluorescence spectrometry is utilized for non-destructive elemental analysis of rocks, mineral, sediments and fluids for geological applications. This XRF facillity has been operational since 2018. A sequential wavelength dispersive X-rays fluorescence spectrometer along with necessary standards has been installed. A fuse bead machine, pellet press and vibratory cup mill have been installed for the sample preparation required for XRF measurements. XRF calibration curves have been made using the available standards. From April-2018 to March-2019, XRF measurements of 904 samples from 7 users from 3 different universities and one institution has been done. The analysis helped the users to do OSL dose rate calculation, geochemical analysis and identification of surface processes of Earth.

X rays diffractometry is used for studying lattice structure to determine minerology of different geological samples i.e. clay, sediments etc. This XRD facility has been operational since 2017. X rays diffractometer has been installed and utilized routinely by users for characterization of their samples. From April-2018 to March-2019, 2081 samples of 28 users from 12 different universities and 3 institutes, were measured using XRD. These analyses helped the users to understand past climatic changes, depositional environment, Earth surface processes. Fig. 3 (a) and (b) shows the XRF and XRD instruments, respectively.

Fig. 3 (a) WD XRF and 3(b) XRD