1. ACCELERATOR

1.1 PELLETRON

1.1.1 Operational Summary

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The performance of 15 UD Pelletron accelerator was quite satisfactory during 1st April 2019 to 31st March 2020. Few problems encountered were resolved properly. There were two scheduled tank openings for maintenance during the mentioned period. The details of these tank opening maintenance are mentioned in maintenance section. The operational summary of the accelerator from April 2019 to March 2020 is mentioned below.

Total No. of Chain Hours	=	5161 Hours
Total Beam utilization	=	3179 Hours
Machine breakdown	=	0308 Hours
Accelerator Conditioning	=	0806 Hours
Beam Change Time	=	0005 Hours
Tank opening maintenance	=	2978 Hours
Beam tuning time	=	0147 Hours
Experimental setup time	=	0020 Hours
Accelerator set up time after maintenance	=	0117 Hours

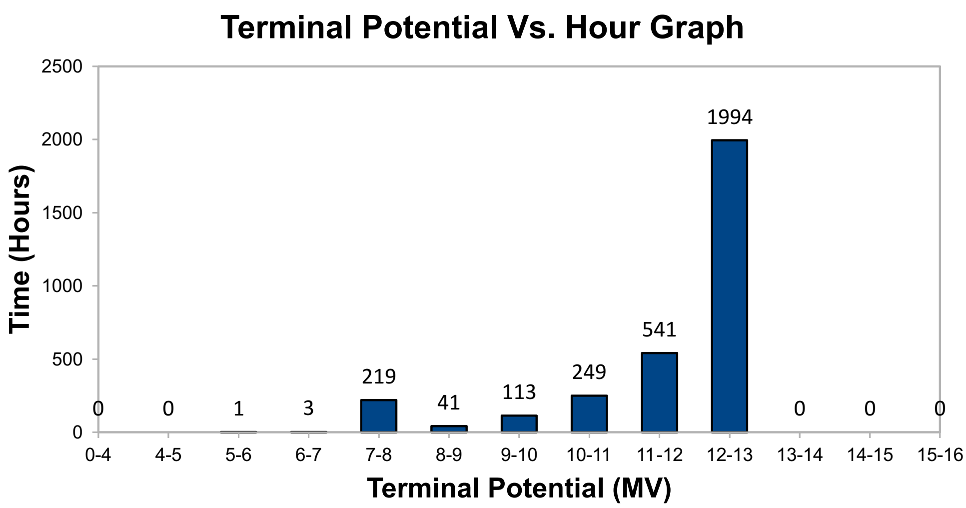

Figure 1.

Total number of 398 shifts were used for experiment during mentioned period, 235 shifts were for pulsed beam and 163 for DC beam. The machine up time for this period is 94.03% and the beam utilization is 61.60%. Figure 1 shows voltage distribution graph of Terminal Potential used for Beam runs for mentioned period. ^{19}F, 6^+, 90 MeV dc beam, at maximum terminal potential 13.99 MV, and ^{7}Li, 3^+, 21 MeV dc beam at the minimum terminal potential of 5.19 MV, were delivered to users. Maximum terminal voltage achieved during conditioning in this year was 15 MV. Figure 2 shows the Chain hours utilization for mentioned period.

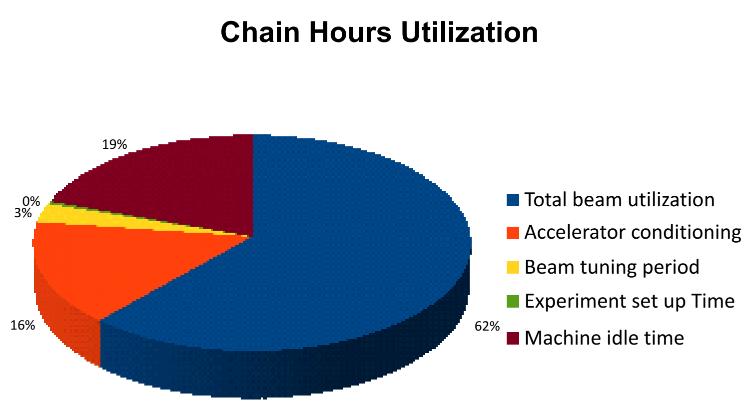

Figure 2.

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)
^{7}Li	7.18%	^{32}S	2.20%
^{12}C	2.21%	^{48}Ti	28.26%
^{16}O	12.11%	^{58}Ni	3.21%
^{18}O	2.55%	^{107}Ag	8.87%
^{19}F	8.86%	^{127}I	4.13%
^{28}Si	9.67%	^{197}Au	1.47%
^{30}Si	9.27%		

Tabel - 1

Pi- chart in figure 3 shows the distribution of delivered beam species during beam run from 1st April 2019 to 31st March 2020.

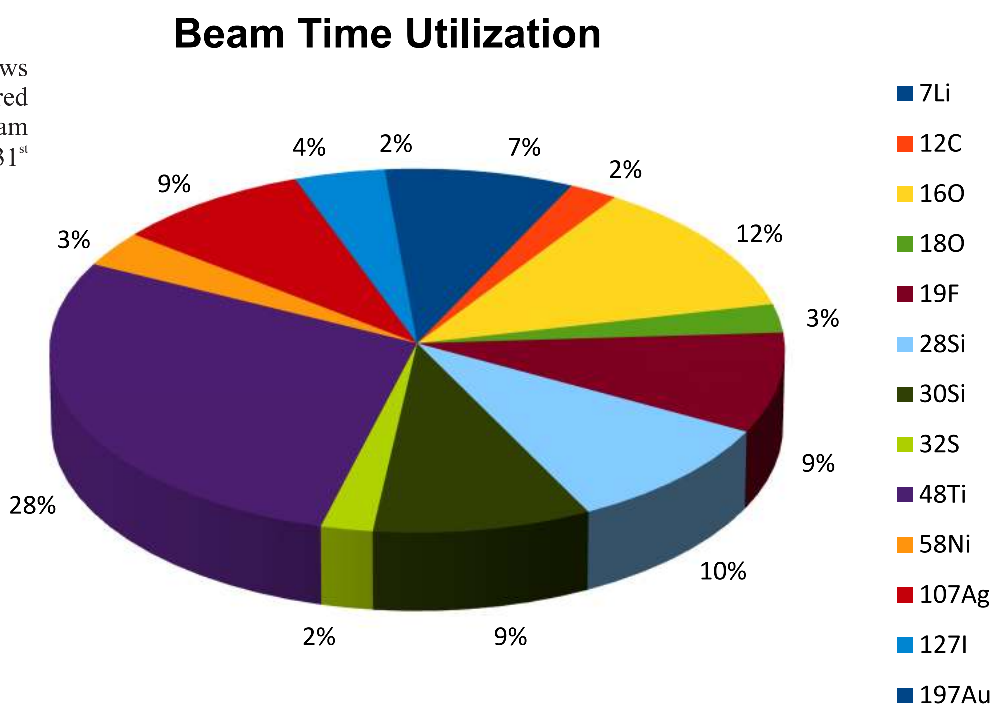

Figure 3.

1.1.2 Maintenance and Development Activities

There were two tank opening maintenances in the last academic year. The first maintenance was scheduled and the second one was unscheduled but it had been taken up keeping in mind the upcoming LINAC runs for which lot of maintenance had to be performed. So, it was converted into a scheduled maintenance. In the first maintenance, the accelerator tank was opened as terminal potential was not going up even after unit wise conditioning. Also, shorting rod operation was not very smooth and some amount of SF6 gas leaked while performing the operation. The tank had not been opened since September 2018, therefore it was decided to open the tank for maintenance which was carried out from 18th April 2019 to 17th June 2019. During this maintenance the 5 new scientists who had joined some time back worked inside the accelerator tank to get trained and get an insight into the accelerator. The second time the tank was opened as the terminal potential was not going above 6.0 million volts and there was no communication with instruments inside Dead Section-2. The tank was opened on 18th September and the maintenance continued up to 15th November. Following major jobs were carried out during these two tank openings:

1) Stripper Foil Loading

Fresh stripper foils were loaded in the terminal during both the tank openings. Approximately 170 home-made EC foils were loaded. As we couldn't get supply of Laser Plasma Ablated foils from University of Munich, Germany we had to go ahead with home-made foils.

2) Column Support Post and Column Resistors

It was observed that links of resistors were damaged in units 16, 17 and 18. These had caused irreparable damage on the column support posts and no new resistors could be mounted on them. The reason for this breakage is unknown. To solve the problem, longer and more flexible connector links were fabricated and installed. The four gaps were shorted, one each in unit 16 and 17, and two in 28. Total number of shortings in high energy section went up from 19 last year to 23. No of shortings in LES remain the same. No column support post was changed during this year.

3) Accelerator Tube Cleaning

Accelerator tubes are tubes through which ion accelerates due to voltage gradient developed because of its special metal ceramic structure. The resistors are mounted on metallic sections to develop the required voltage gradient. Corroding of metallic section was observed due to minor sparks. This leads to deposition of dust (which may be a by-product of SF_6 gas). Because of this dust, the voltage handling capacity of the tubes went down. Therefore the tubes hade to be cleaned. Also lot of dust was generated due to breakage of rubber couplers. Therefore cleaning was necessary. All the resistors of the tubes were removed and the gaps were cleaned. Resistors were mounted back after measuring the resistance and wiping them with lint-free tissue paper.

4) Charging System Maintenance

It was observed that the charging efficiency of charging system 2 was not working properly. The chain 2 was carrying less current compared to chain 1 and the charging current was saturating after reaching a particular value. The inductors of the chains were adjusted. The pulley of charging side of the chain was changed. The efficiency of the system improved after the adjustments.

Lot of grease came out of pillow box of chain number 1. Also there was smell of grease burning. Vibration analysis of the frames which holds charging chain pulleys was performed. It was found that there was more vibration in pulley of chain number 1. Charging system 2 looked ok. Charging chain 1 and pulley were removed and the whole pillow block assembly was replaced with a new assembly. Pulley and chains were reinstalled. Vibration analysis was performed again. It was found that vibrations of both the chains are same now. If this maintenance would not have been carried out there could have been a major accident which could have resulted in large scale damage of charging system 1.

5) Mechanical System Maintenance

Bearings are becoming loose link in the smooth operation of the Pelletron. In all, 56 numbers of bearings were changed in this year. In addition to this, 3 numbers of Bearing Box assemblies and 6 numbers of rubber couplers were changed. These numbers are on higher side. The second tank opening was mainly due to breakage of rubber coupler between unit number 22-23 due to which rotating shaft stopped moving and no power was getting generated in Dead Section-2. As a result there was no communication with instruments out there.

6) Issue with Fiber optic Channel

One of the channel of fiber optic cable which transmits and receives signals from high voltage area of accelerator was found to be not working. Due to this issue we were unable to move one of the essential section of accelerator “Foil Stripper D2”. Another free channel of fiber optic link was identified and signal was switched to the particular channel. The movement of foil stripper D2 is now normal and hassle free.

7) Corona Probe Maintenance

All seven needles of corona probe were changed as they had gone blunt. This bluntness of needles could have resulted in instability of the terminal voltage which could have created problems for smooth operation during the LINAC run.

8) Routine Maintenance

Measurements of all resistors, column support post gaps, hoop screw measurements and replacements, operation of earthquake rams and routine cleaning of Pelletron accelerator was performed. All these works are equally important for the smooth operation of the accelerator.

9) Other Maintenance outside Tank

a) GVM related problem

GVM of 15 UD Pelletron accelerator started malfunctioning in the first week of August. It was not showing correct terminal voltage. All in situ tests didn't solve the problem. Low resistance between stator and rotor was observed. After servicing it showed open resistance. The GVM was installed back.

b) Problem in 04 Area

04 area of 15 UD Pelletron accelerator, which is after analyser magnet is equipped with an aluminium sheet (bat) which intercepts the beam and gives information about timing signals of pulsed beam via gamma generated due to nuclear reaction. In the month of February 2020 in between the LINAC beam run,. the bat became loose and fell down. Although the beamtime was not stopped due to this event, but it had to be installed back for other upcoming pulsed beam runs through LINAC. The area was vented and the bat was installed back and the area was pumped soon after that.

1.1.3 Ion Source Activities

Operation

The source operated satisfactorily during April 2019 to March 2020. To ensure smooth operation of ion source, preventive and routine maintenance were carried out and cathodes were loaded routinely to deliver required beam to the users. 7Li, 12C, 16O, 19F, 28&30Si, 32S, 48Ti, 58Ni, 107Ag, 127I and 197Au species with energy range from 150 keV to 200 keV were developed from the source in the academic year. High currents were produced in the case of Ti, Si, F and O as the beam had to be chopped and bunched with different repetition rates as per nuclear physics user requirements.

Cathode Loadings

Cathodes were loaded in the source on 8th July 2019, 7th August 2019, 2nd September 2019, 19th December 2019, 12th January 2020 and 10th February 2020 as per the beam schedules of various users decided by the BTSG group.

Maintenance

1) Preventive Maintenance

The source was opened in the month of May 2019 for routine maintenance. All the electrical connections and coolant connections were removed. Source was vented by argon gas. Cesium reservoir was safely removed and kept in argon atmosphere. All sections of ion source viz, ionizer, immersion lens, flanges and Einzel lens were cleaned with alcohol using lint free tissue paper. All section of source looked o.k. therefore nothing had to be replaced. Source was assembled back and reinstalled. Cesium was not changed this time. Source was evacuated, all electrical connections and coolant lines were installed. Source operated satisfactorily after the maintenance.

Source was again opened in the end of November 2019 for preventive maintenance keeping in mind upcoming LINAC runs where ion source may need to operate in extreme conditions to generate high currents. Once again total source were dismantled cleaned and assembled back. Cesium was loaded after disposing older stuff. Einzel lens looked fine with all gap resistances higher than 15 GΩ. It was cleaned from outside and all the resistors were involved. Source is still in the operation after the maintenance.

2) Breakdown Maintenance

This year there was only one minor breakdown maintenance in the ion source. In January 2020, Cathode and Extractor power supply stopped working after power failure. This happened during ongoing experiment. The power supply was changed with a spare supply and the experiment was started without causing any delay to the user.

1.1.4 Beam Pulsing System

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Operation

235 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. Out of the 235 shifts, 3 shifts were utilized for the testing of Beam Pulsing System and 28 shifts by users to perform their experiments in different experimental lines using Pelletron only. The beams bunched were ^{16}O, ^{19}F and ^{32}S.

LINAC was used for remaining 204 shifts, 39 shifts for tuning and 165 shifts for users' experiments. Beams bunched were ^{19}F, ^{28}Si, ^{30}Si and ^{48}Ti.

All the pulsed beam runs were quite stable with few breakdowns.

Maintenance

a) Chopper Maintenance

Routine maintenance of chopper was carried out by tuning of output stage of 100 W, 4 MHz It was checked with 50 Ω pure resistive dummy load, and found satisfactory. The output of the amplifier was then 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 overnight and its stability was satisfactory.

100W, 4 MHz Chopper amplifier broke down twice during LINAC runs. First time, the problem was solved by replacing two pentode valves (6146B) at the output stage of the amplifier. Fluctuation at the output of amplifier was also noticed. This fluctuation resulted due to the fluctuation in DC biasing to the control grid of first stage pentode valve (6CL6). Problem was analyzed and an OP Amp OP-14 was replaced in amplitude control board to solve the problem. Second time, mains fuse was blowing off. The output stage of amplifier had to be re-tuned to solve the problem. It was also noticed that the output of amplifier was fluctuating due to the fluctuation in line voltage also, although the mains voltage is supplied through UPS. To further investigate this problem, the UPS has to be checked thoroughly.

b) Traveling Wave Deflector (TWD) Maintenance

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

During the LINAC runs, TWD stopped working twice. First time, Plate voltage of tetrode valve got tripped off due to failure of 6th channel. Problem was the failure of its driver circuit. The driver circuit was repaired to solve the problem. Second time, again Plate voltage to tetrode valve got tripped off due to failure of 3rd channel. Again the respective driver circuit was repaired to solve the problem.

To investigate the problem of frequent failure of driver circuits a breakdown maintenance was planned. In this maintenance, few clipper circuits were repaired and two TWD channels were made active. The frequent failures of driver circuits of TWD amplifier was analyzed and found that Triple Line Receiver ICs for TTL (SN75122) were misbehaving. There are total four SN75122 for twelve channels driver circuit. As SN75122 is now obsolete, all the four Triple line receiver were replaced by its equivalent SN75124. Thereafter, TWD worked satisfactorily.

1.1.5 Low Energy Negative Ion Implanter Facility

1. Operation

The ion implanter accelerator facility was operational for implantation experiments from April to 9th August 2019 and then 8th January, 2020 onwards. The facility experienced numerous breakdown maintenances in this academic year such as failure of control system and ion source related troubles etc. Altogether, 17 numbers of users from different colleges, universities and institutes availed the beam time in 17 runs. The particulars about the implantation experiments performed during this period are given below:

1. No. of users: 17
2. Number of beam runs: 17
3. Total time of machine run other than beam on the target = 171hrs
4. Total time spent for machine test run =720 hrs
5. Total number of shifts utilized/beam on the target: 57
6. Total number of samples implanted: 702
7. Ion fluencies used: $5x10^{11}$ to $1x10^{17}$ ions/cm^2

8. Ion species utilized: ^{7}Li, ^{28}Si, ^{31}P, ^{48}Ti, ^{52}CrH$_2$, ^{56}Fe, ^{58}Ni, ^{59}Co, ^{63}Cu, ^{74}Ge, ^{107}Ag, ^{197}Au

9. Energy range utilized : 30 to 200 KeV

2. Maintenance and Development Activities

The implanter accelerator is generally in regular operation; it stops only when cathode sample loadings and preventive maintenances are essential in regular interval. Due to occurrence of various troubles faced by the facility listed below, the operational status of the machine was not satisfactory.

2.1 Preventive Maintenances

The accelerator system had to stop for magnet power supply repairing work in August, 2019. The cathode and Einzel lens showed voltage fluctuations and could not hold normal operational values. Ion source components got dirty when it ran for longer duration. Since its opening in May, 2018, it had run more than a year without any maintenance. The ceramic surfaces of Einzel lens were found almost shorted showing few Mega Ohm of insulation. Preventive maintenance of ion source and Einzel lens system were carried out by cleaning them. Ion beam could be extracted from the source. However, extractor voltage could take only 1KV. All the possible causes of fault, such as damage in 150 Mega Ohm resistors, their electrical connections to the insulation gaps of Einzel lens and extractor bleeder resistors were examined. A sharp pointed Aluminum foil piece used for Al gasket holding while joining flanges of Einzel lens and beam line was found very close to the drop down bracket which was at High Voltage Deck ground potential. Aluminum foil piece could not be seen as it was covered with paper tape.

2.2 Breakdown Maintenances

Number of breakdown maintenances were also done which are mentioned below.

i) In April, 2019, due to incorrect output of CAMAC, the electrostatic steerer voltage showed fluctuations, it took very high value without even increasing its control voltage. The damaged DAC module was replaced. There was an instance of server computer and Ethernet cable going bad in May, 2019. The control system files were reinstalled in another computer; cable was replaced and the system was made operational.

ii) In July, 2019, after thunder and rain, the electrical power of whole implanter facility went off. Subsequently, the vacuum of whole accelerator system including ion source went bad. Even though power resumed, all beam line components such as Electrostatic Quadrupole triplets, Electrostatic Steerer, Beam Sweep Amplifier, FCs and log amplifiers etc. stopped functioning. Each one was examined. The fuses and resistor of those modules were found burnt. They were replaced and made operational.

iv) In September, after the preventive maintenance, ion source was put on for testing. High voltage deck showed fluctuation by 1KVand produced lots of X-rays of almost 100µR/hr or more even at a very low voltage of 30KV. X-rays were mostly at background noise level. It was due to lots of dust influx inside the implanter laboratory from beam hall II area due to ongoing civil maintenance work. Moreover, the floor of the implanter required painting. The whole vacuum system and electrical system were shut and the implanter accelerator was kept under polythene wrap to avoid the dust. However, ion source vacuum pump was kept on to preserve cesium inside its reservoir in the ion source.

v) In November, after the floor painting work, the whole beam line was cleaned. The vacuum of accelerator system restored. While operating ion source, cathode current fluctuated randomly from 0 to 15mA, thereby, causing fluctuation in its voltage. Ion source was baked for nearly 1 day. At deck high voltage, HVS, 120 KV, X-rays of more than 100uR/hr were produced. The machine was put on conditioning; with time, its activity reduced. Finally, the accelerator could run at its highest energy, 200KeV, 500nA of 59Co beam with X-Ray, 150uR/hr. Ion source was left running overnight in low ion source parameters at HVS of 100KV, 58Ni. Filament was found broken next morning on 18th December, 2019. Cathode drew current up to 13mA at 1.5kV. Cathode wheel was removed and cleaned. Both filament and cathode power supplies were replaced. However, the new cathode supply went bad.

vi) Magnet tripped quite often and its polarity kept changing by itself. There was fault in input signal from the IGOR control system. It was rectified. However, the magnet and control system functioned abnormally with a deck voltage of more than 180KV. Cooling fans were installed above the control crate to have proper cooling of those modules. From 8th January, 2020 onwards, implantation experiments that utilized lower energy ion beam began with local IUAC users,.

vii) On 31st January, 2020, ion source vacuum disturbed to ~ 2x10^{-6} Torr while conditioning the accelerating tubes. Line heater was observed red hot. Line heater and cesium focus were taking full values, focus, 0.2kV, oven heater, 35Volt. The cable of the line heater was burnt. Cesium focus resistor got damaged. The problem traced to the faulty control system. Loads were detached. All the power supplies of ion source components were examined and found in normal working condition. Control system ADC, DAC cards were found burnt. After fixing the problems, the quality and quantity for cesium leftover were checked. Ion source was observed in normal operation giving sufficient beam current constantly for nearly one week. Therefore, beam delivery to the user started.

viii) In February, 2020, during the implantation experiments, Ag ion beam current slowly reduced from 1µA to few hundred nA. Implantation experiment stopped. Cesium loaded.

3. New Beam Development

As per user's requirement, time to time, attempts were made to develop new ion beams in addition to improving ion intensities of various ion species. Lead and Chromium cathodes were prepared with the help of available literatures. Lead ion current intensity showed improvement. Molecular negative ion beam, $^{52}CrH_2$ with a ion intensity of 1µA was developed and utilized for implantation experiments.

1.1.6 Utilization of Beam Runs Using 15 UD Pelletron Accelerator and LINAC from 1st April 2019 to 31st March 2020

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.

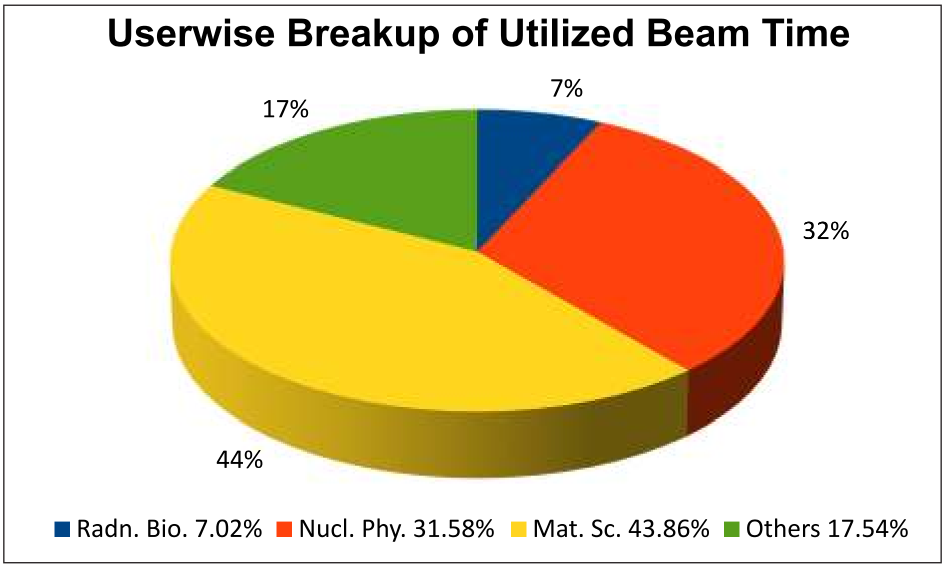

Figure 4.

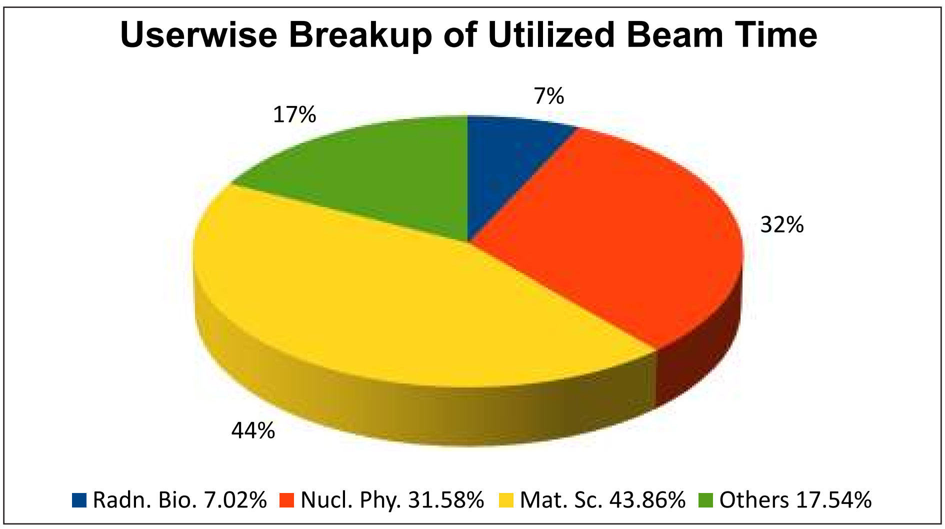

Figure 5.

Table 2. User List : April 2019 to March 2020

Sr. No.	University / Institute / College	Shift Utilized
1.	Aligarh Muslim University	1
2.	Amity University, Noida	8
3.	Bareily University	13
4.	Calicut University, Kerala	31
5.	DA Vishwavidyalaya, Indore	3
6.	Delhi University	13
7.	Guru Ghasidas University, Bilaspur	20
8.	GGSI University, New Delhi	6
9.	Government College, Faridabad	2
10.	HNB Garhwal University, Tehri	3
11.	IIT Bombay	2
12.	IIT Delhi	3
13.	IIT Roorkee	3
14.	IIT Ropar	1
15.	INMAS DRDO, Timarpur, Delhi	1
16.	ISRO, Bengaluru	7
17.	IUAC (RAs), New Delhi	8
18.	IUAC (Students), New Delhi	18
19.	IUAC, New Delhi	91
20.	Jawaharlal Nehru University, New Delhi	2
21.	Kalyani University, West Bengal	3
22.	Karnataka University	18
23.	Kurukshetra University	20
24.	MS University Baroda, Vadodara	4
25.	MRI University, Faridabad	3
26.	Pune University	3
27.	Punjab University, Chandigarh	108
28.	VIT, Jaipur	3

1.2 SUPERCONDUCTING LINEAR ACCELERATOR (SC LINAC)

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1.2.1 Operational Details

During December 2019-March 2020 ion beams from the Superconducting Linac (SC Linac) were delivered in different experimental lines - Hybrid Recoil Mass Analyser (HYRA) and National Array of Neutron Detectors (NAND) for scheduled experiments. During this cycle, ion beams viz. $^{28,30}Si$, ^{19}F and ^{48}Ti were accelerated. During the beam acceleration, maximum energy gain of about 9.6 MeV/q had been achieved from the Linac. This corresponds to an operational accelerating gradient in the QWRs which is typically 5% less than the maximum achievable value. The beam transmission loss through Linac was observed to be around 15%, which is reasonably good, but can certainly be improved. The ion beams accelerated using the Linac in this cycle are listed in Table-1; beam energies are those requested by the users.

Table 1. Beam acceleration schedule using Linac

Experimental Area	Beam	Schedule	Energy Range Delivered (MeV)
HYRA	$^{48}Ti^{14+}$	6/1/2020 – 17/1/2020	281 - 214
NAND	$^{48}Ti^{14+}$	18/1/2020 – 27/1/2020	280 - 192
HYRA	$^{30}Si^{11+}$	12/2/2020 – 19/2/2020	212 - 125
NAND	$^{30}Si^{11+}$	22/2/2020 – 27/2/2020	210 - 165
HYRA	$^{19}F^{9+}$	4/3/2020 – 11/3/2020	160 - 105
NAND	$^{28}Si^{11+}$	13/3/2020 – 21/3/2020	210 - 180

The Linac operation was very stable with one odd cavity only going out of lock within a period of one-two days. Due to this excellent stability, only <1% beam time was lost due to Linac related problems. The Capacitive Pickup device was used to verify the beam energy during the energy tuning and change of beam energy from Linac. The energy gain from the three Linac cryostats was more or less uniform as shown in figure 1.

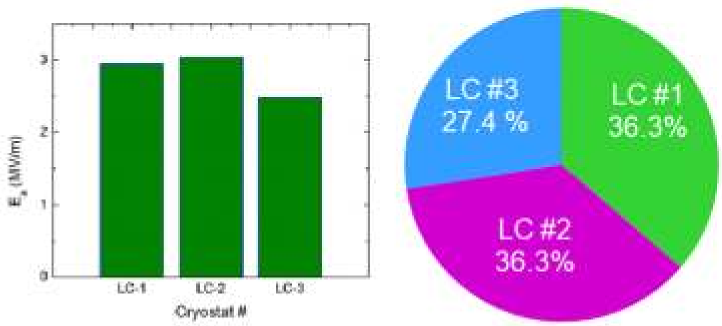

Figure 1. Energy Gain from three Linac Cryostat

The accelerating gradients of all the resonators during this cycle of Linac operation is shown in figure 2.

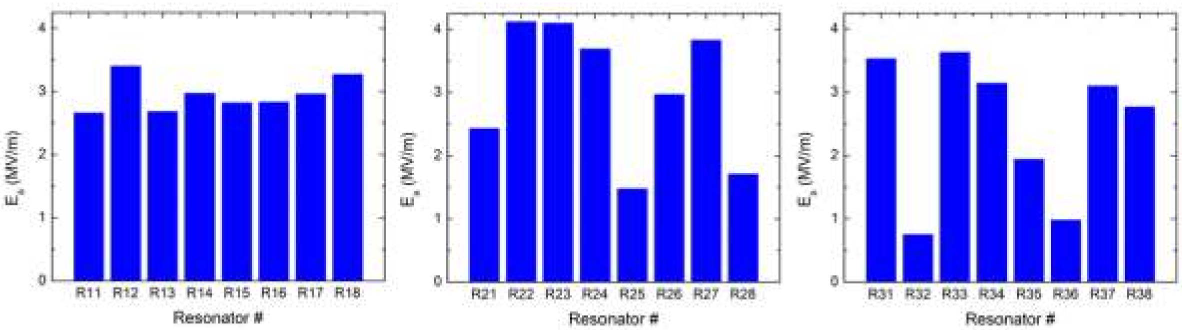

Figure 2. Accelerating gradients during linac operation

It is clear from figure 2 that the performance of most of the resonators is satisfactory with operational gradients above 3 MV/m. A few cavities, like R21, R25, R28, R32, R35, R36 and R38, however, need attention as their field gradients are low. They will be taken down in batches (e.g. R32 & R36, R25 & R28 etc.) and tested offline to identify the cause of their low performance so that suitable treatment can be applied to improve their performance. Several treatment methods and their effectiveness have been systematically studied over the past few years [1] which should allow us to pick the appropriate treatment that would be most effective for a given QWR. Although accelerating field performance of R26 is high, the same could not be phase locked at higher gradient due problem associated with the drive coupler loop.

At the start of the run, to improve the performance of the QWRs, apart from high power pulse conditioning, high power helium pulse conditioning was also performed in linac cryostat # 2 (LC#2). Several cavities in LC#2 have shown substantial improvement in their performance as evident from the improvement in the performance of R27 shown in figure 3 as an example. The improvement in R26 was equally impressive; before the helium conditioning its gradient dropped from 4.63 MV/m at 4 W input power to 2.07 MV/m at 6 W power. However, after helium conditioning, although its performance at 4 W input power did not show any significant improvement (it achieved 4.79 MV/m at 4 W input power), its performance improved dramatically at 6 W power to 5.49 MV/m. It is planned to provide the capability to perform high power helium conditioning in LC#1 and LC#3 also before the next cycle of Linac run.

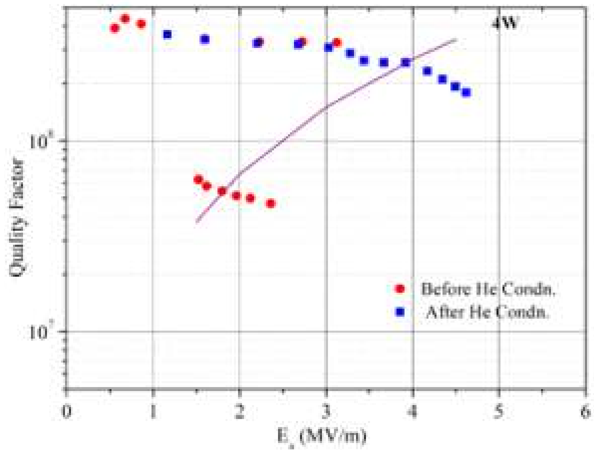

Figure 3. Q-Curves of R27 before and after Helium High Power Conditioning.

1.2.2 Relocation of LINAC Control Room

Earlier the linac control racks were located near the linac cryomodules. As this location restricted certain operations due to radiation exposure and also from radiation interlocking point of view, it was decided to relocate them. The new control room has been setup on a newly constructed mezzanine platform 2.20 m above ground level in the adjacent cryogenics room. In figure 4, the new control room is shown. All activities performed before beam acceleration, e.g. multipacting Conditioning, Q curve measurements, high power pulse conditioning, high power helium pulse conditioning, coarse tuner adjustment, adjustment of drive coupler to achieve the desired coupling constant, pumping and purging of the slow tuner lines and frequency tuning by the PWM based pneumatic frequency tuner etc. were all carried out from the new control room. Some of these controls are also available in the main control room (adjacent to the Pelletron controls) for operation during beam run.

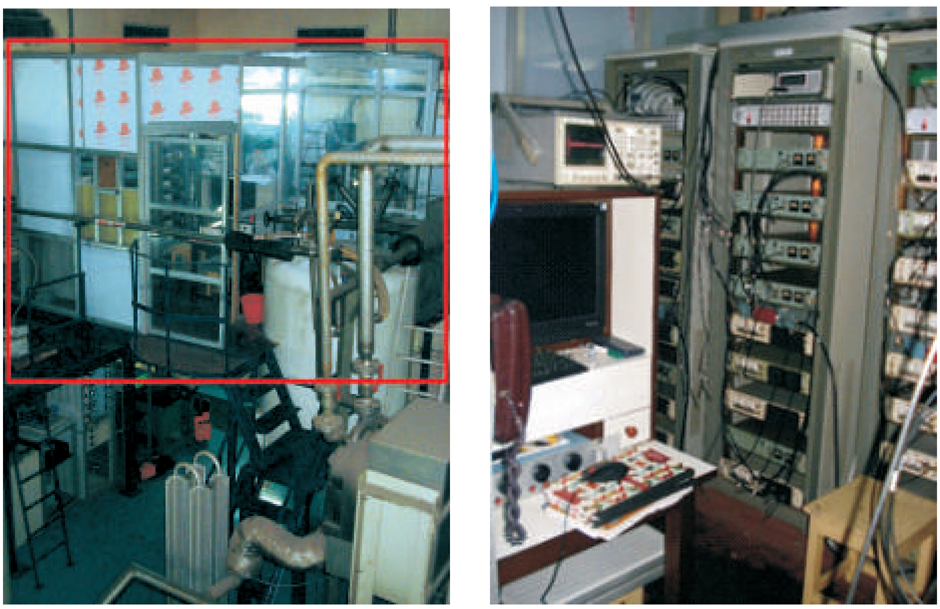

Figure 4. The new control room for Linac operations; left: the mezzanine floor for the control room (red box), and right: the inside of the control room.

References

[1] Abhishek Rai et al. Superconductor Science and Technology 32 (2019) 095003

1.2.3 Superconducting Niobium Resonators

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The construction of six quarter wave resonators (QWRs) and extra slow tuner bellows assemblies as spares for the superconducting linac, has progressed well. For carrying forward the studies on improving the accelerating gradient and quality factor in niobium quarter wave resonators, a QWR that had been set aside from the production lot due to its high resonance frequency, has been reworked upon and completed. The 2^{nd} prototype low beta resonator is also ready for the installation of the outer helium vessel, which will provide another resonator design for validating such studies.

1.2.3.1 Construction of Spare QWRs and Slow Tuners for Linac

Construction of the six QWRs and additional slow tuner bellows as spares for the superconducting linac has progressed further. They will also be useful for conducting studies aimed at improving the accelerating gradient and quality factor in niobium quarter wave resonators as well as for other offline development works. Several parts / sub-assemblies for the resonators, e.g. the drift tubes assemblies, open-end flanges, slow tuner bellows, stainless steel outer helium vessels, etc. have been completed. In figure 1, several parts and sub-assemblies for the spare resonator construction are shown.

Figure 1: Clockwise from top-left: (i) elements of the niobium drift tube assemblies, (ii) weld rings for the slow tuner bellows, (iii) EBW set up for welding the drift tube beam port assembly, (iv) leaves for the slow tuner bellows, (v) SS outer helium vessels, (vi) EBW set up for welding slow tuner bellows, (vii) open-end flanges, and (viii) drift tube beam port assemblies before welding.

1.2.3.2 Completion 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 quarter wave resonator; QWR-I11, which had been kept aside due to its high resonance frequency, has now been completed. The resonator had been cut open and its central conductor was shortened to the correct size to obtain the desired frequency. The resonator was electropolished and heat treated as part of the pre-test processing sequence. Subsequently the outer stainless steel helium vessel was installed. The resonator has been successfully leak tested and separately pressure tested in the test cryostat. In figure 2, the different stages of the reworking have been shown. We plan to initially test the resonator to establish a baseline test at 4K before subjecting it to further processing such as 650°C heat treatment, 120 °C baking, N-doping, N-infusion, etc. to study the improvement in its accelerating gradient and quality factor.

Figure 2: Centre: QWR-I11 after completion. Clockwise from top-right: (i) parts of the niobium central conductor – the loading arm with top flange (in the background) and drift tube (in the foreground), (ii) welding of the two parts of the central conductor, (iii) EBW of the niobium outer housing with the extension tube, (iv) the two major niobium sub-assemblies of the resonator before they were attached.

1.2.3.3 Completion of the 2nd Prototype Low Beta Resonator

The first prototype low beta resonator had performed exceedingly well exhibiting a very high quality factor at 4.2K (>1.2510^{9}) and very easily achieving the nominal design goal gradient. In order to validate the various processing techniques that are being studied [1], performing the tests on the low beta resonator design, in addition to the QWR design (installed in the superconducting linac), provides further credence to it. Some of the processes have already been applied on the first low beta resonator and tested. In order to expedite the turn-around time for processing and testing, it is essential to have additional resonators available in hand. In view of this, the 2nd low beta resonator is also being completed now. The resonator has been electropolished to remove approximately 200 μm from the RF surface and is awaiting for the high vacuum furnace to be available, which has been down for the past several months awaiting the replacement of the water cooled current leads (they have arrived but not yet installed), for the heat treatment. Thereafter the outer stainless steel helium vessel will be installed on the resonator to complete it.

Reference:

[1] A. Rai et al., Superconductor Science and Technology 32 (2019) 095003

1.3 PARAS (1.7 MV Pelletron Accelerator and RBS Endstation)

G R Umapathy, Sunil Ojha, K Devarani, G Raturi, Jawant Singh, Pranav Singh, Suraj Kumar, Mohan Nishal, N S Panwar, M P Singh, Rakesh Kumar, Jagdish Prasad, Chandra Pal, P Barua, V P Patel, Rajveer Sharma, M Sota, S Gargari, R Joshi and S Chopra

Operation: The 1.7 MV Pelletron accelerator for Rutherford backscattering facility was utilized by 46 users from 28 Universities, colleges and institutes. In total 1097 measurements were performed in this period. Backscattering, Resonance RBS of Oxygen and Nitrogen and Channeling measurements were performed in routine for users/students. RBS is the most suitable technique to gauge accurate thickness and composition of the thin film samples of different areas of research like nuclear targets, thin or multi layered films on substrates like Si, SiO_2, Ge, GaAs etc. The thin targets of around 100 nanometers, and thick targets (~1 um) of nuclear physics were routinely analyzed using the RBS facility. The RBS channeling of epitaxial layers, low energy ion implanted and processed samples were analyzed for quality of epitaxial growth and/or ion implanted damage estimation. Resonance scattering 16O (α, α)16O at 3.045 MeV and 14N (α, α)14N at 3.69 MeV were performed for oxygen and nitrogen depth profiling in thin films.

1.3.1 Maintenance

1.3.1.1 Ion Source Maintenance

Ion source maintenance was performed once during this academic year. Lot of fluctuation was observed in probe voltage which resulted in very low beam current from source hence it was opened for maintenance. The ion source components were found chocked with rubidium depositions preventing helium beam to come out of exit aperture. The source was opened, cleaned thoroughly, baked and reassembled. Two ampules of 5 grams rubidium for charge exchange were loaded in argon atmosphere. After evacuation, the source was operated. Continuous and stable He beam was achieved after few hours of conditioning.

1.3.1.2 1.7 MV (5SDH-2) Pelletron Accelerator and Endstation Maintenance:

Many problems were observed during the operation of 1.7 MV tandem accelerator. Some of the problems were: charge loss, instability in Terminal Potential (TP) and fluctuation in Charging Power Supply (CPS). Charge loss means difference between the charging current and drain current in electrostatic accelerators. When drain current is considerably lower than charging current it leads to instability in the voltage of accelerator. The 5SDH-2 tank was opened for the first time after its installation in the year 2010. Before opening accelerator tank, to understand the problem, externally simulated signals were generated and it was inferred that the reason for charge loss is either mushroom head of corona probe or the deposition on the outer surface of tank.

The SF_6 was transferred to storage tank and corona probe assembly was removed. Corona probe needles were found in deteriorated condition and mushroom head surface had lot of dust deposition on it. A new set of corona needles were installed after cleaning the outer surface of the mushroom head. But this did not solve the charge loss problem, therefore the accelerator tank was opened.

The chains, terminal and other parts like casting, prespex shielding were covered with black sticky depositions. The spark marks on terminal shell, chains, inside tank wall and other parts were cleaned thoroughly. The chain testing was performed in open atmosphere by connecting microammeter in series. Chain 1 current was not stable at charging voltage above 8 kV whereas Chain 2 was found to be stable. The condition was acceptable, as the stability in SF_6 is supposed to be better than in open atmosphere. The different components of accelerator were assembled inside the tank and the tank was attached to the beam line. Beamline was evacuated and SF_6 was filled in the tank up to 50 PSI pressure.

The high voltage cable connecting probe to Power supply was found to be punctured. It is supposed to hold 10 KV but it was breaking down at 4.7 KV. A new HV cable was made and installed. The charge loss measurements were performed with dry nitrogen filled in the tank up to 45 PSI. With new set of probes and cable, no charge loss was observed.

The SF_6 leak through the CPS feedthru as mentioned in last year report was also fixed by replacing the feedthrus with new set during maintenance.

There was vacuum break down in high energy section of accelerator due to failure of DCU 200 vacuum controller. It was replaced by spare DCU 200 available with Pelletron group. Also, a vacuum leak was observed in the High Energy section of accelerator. The leak detection was performed with leak detector. The leak rate of 10^{-5} mbar-lit/s was observed at the flange of Faraday cup 2 in HE section. This happened due to deterioration of NEC gasket because of water dripping through cooling arrangement. The beamline was vented and gasket of faraday cup flange was changed. Pressure in the range of 10^{-7} T achieved in the beam line within a day.

The control system of RBS endstation developed a bug; the serial ports of the control computer are not communicating with the endststion controls. Therefore the facility is currently not operational. We are in touch with the manufacturer (NEC) to resolve this issue.

Figures: (1) Inside view of the HE section of 1.7MV (5SDH-2) Pelletron accelerator. (2) Corona probe needles and dust deposition around mushroom like head. (3) Spark marks on the terminal near to probe needles. (4) Rb choked ion source components before cleaning. (5) New chain feed through. (6) Inside view of terminal of 5SDH-2 Pelletron accelerator.

1.4 AMS AND GEOCHRONOLOGY FACILITIES

1.4.1 Accelerator Mass Spectrometry

Deeksha Khandelwal, Leema Saikia, Anit Dawar, Meenakshi, Pavitra V. Kumar, Umapathy G R, R. Sharma, Soumya Prakash Dhal, Jaswant Singh, N S Panwar, Pranav Singh, Jagdish Prasad, Pankaj Kumar, S. Ojha, S. Gargari, R. Joshi 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 is in operation since March 2015. The 500 kV tandem ion accelerator based XCAMS, procured from National Electrostatic Corp. (NEC), USA is used for AMS measurements. 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 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). The graphitization of dissolved inorganic carbon from ground water samples has also been started this year. During April 2019-March 2020, 523 samples have been pre-treated and graphitized by 28 users from different universities and institutes for their research work.

1.4.1.1.1 Graphitization of dissolved inorganic carbon (DIC) in ground water samples

Carbonate handling system is utilized to graphitize carbonate samples. This system can also be utilized to graphitize dissolved inorganic carbon in ground water samples. Altogether 30 ground water samples have been graphitized using this system. In total 21 mL water for each sample was taken in three 12 ml vials (7 mL in each) and flushed with helium gas (100 ml/Min flow) for 10 minutes, 1 ml H_3PO_4 was added in each vial and all the vials were heated at 90°C temperature for 2 hrs. The carbon dioxide produced is transferred to zeolite trap in the AGE where it is graphitized with hydrogen gas over iron powder at 580°C temperature.

The obtained CO_2 in these samples was in the range of 400–1000 microgram. The standard and blank samples for DIC were prepared by dissolving IAEA C2 and C1 samples in the acidic water (MQ water with 1 mL H_3PO_4) and later on graphitized in the same way as real samples. Fifteen samples out of these graphitized samples have been measured using XCAMS and rest samples will be measured in the next radiocarbon run.

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

There were few renovation activities planned and performed inside the clean chemistry laboratory, including replacement of 6 HEPA filters as well as covering of working tables with Teflon clothes. After completion of the renovation work, following activities were conducted:

- Three quartzite samples were processed for pre-concentration of Beryllium and Al. In addition, one procedure blank was also prepared.
- 14 standard samples were prepared in two different batches. One batch was treated with HF in order to reduce Boron.
- 23 rock samples were digested and B-solution were prepared for trace elements and REE measurement using ICP-MS.
- 12 standard samples were also prepared from SRM 4325 and SRM **3105a.**

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 705 samples of ^{14}C and ^{10}Be have been measured this year. 26 users from different institutes have utilized this facility for their research work.

1.4.1.3.2 Cathode Pressing Using Automated Electric Cathode Press

A new automated electric cathode press (Model No – NEC ECP 890) was procured. This automated press packs material in different sample holders (cathodes) with constant pressure which is essential for reproducibility of current, and it also helps easier handling in pressing large number of cathodes making the whole process more user friendly. The cathode press was tested by pressing standard and blank graphite samples at different forces (120, 150, 180, 198 lbf) and results were compared with the same graphite samples pressed with manual press at 200 psi pressure. We obtain similar current and ratios as obtained using manual press. Now this press is routinely utilized for the sample material packing for ^{14}C, ^{10}Be and ^{26}Al AMS measurements.

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 breakdown maintenance in December 2019. The immersion lens voltage was following the cathode voltage. The source was opened, cleaned, re-assembled and brought back to operation. However, the same problem again occurred in January after two ^{14}C measurement runs. The source had to be opened again and it was cleaned, re-assembled and brought back to operation.

ii. 134 MC SNICS source was opened for routine maintenance in October 2019. The source was cleaned and reassembled. After maintenance, extractor voltage was fluctuating after reaching at 15 kV. Einzel lens assembly was opened, cleaned and installed. Still extractor was showing the same problem. Ionizer current was also fluctuating. Source was again opened; ionizer was cleaned and re-assembled. Ionizer is working fine but Einzel lens maintenance is still going on.

iii. Power supply of IUAC 1 – 2 slave computer was not working. It was replaced with a new power supply.

1.4.2 National Geochronology Facility

Deeksha Khandelwal, Leema Saikia, Anit Dawar, Devendra Kumar Joshi, Meenakshi, Pavitra V. Kumar, Atul Kumar Singh, Umapathy G R, R. Sharma, Soumya Prakash Dhal, Neelratan Singh, Madhav K. Murari, Pankaj Kumar, S. Ojha, S. Gargari, R. Joshi, P.K. Mukherjee and S. Chopra

The objective of the project is to setup a national 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:

1.4.2.1 Femtosecond Laser Ablated High Resolution- Inductively Coupled Plasma Mass Spectrometer (Fs-LA-HR-ICPMS)

HR-ICP-MS (model: Thermo Scientific, Element XR) coupled with femtosecond Laser Ablation (model: Teledyne), shown in fig. 1, is now extensively used for isotopic ratio measurements. The instrument can be used in solution mode, where a peristaltic pump is used to aspirate the sample or in solid mode, in which the femtosecond laser is used to ablate the sample and the aerosols generated are introduced into the mass-spectrometer for measurements. For doing sequence of samples in liquid mode automatically, the instrument is equipped with auto-sampler having 10 standard samples and 120 samples slot capacity.

Figure 1: HR-ICPMS coupled with Fs Laser and Prepfast auto-dilution system for automatic precise inline dilution (x 400)

The robust calibration of an instrument is very important to get precise and accurate measurements. The optimisation of Laser was done by ablating different Zircon grains. These grains were analysed under microscope to check the morphology of the craters created by laser ablation. The grains were also analysed under Scanning Electron Microscope (SEM) for the dimensions of the craters to verify whether the craters of desired size are ablated or not. The results were found to be satisfactory. The depth of ablation was also analysed using an Atomic Force Microscope (AFM) (Fig. 2).

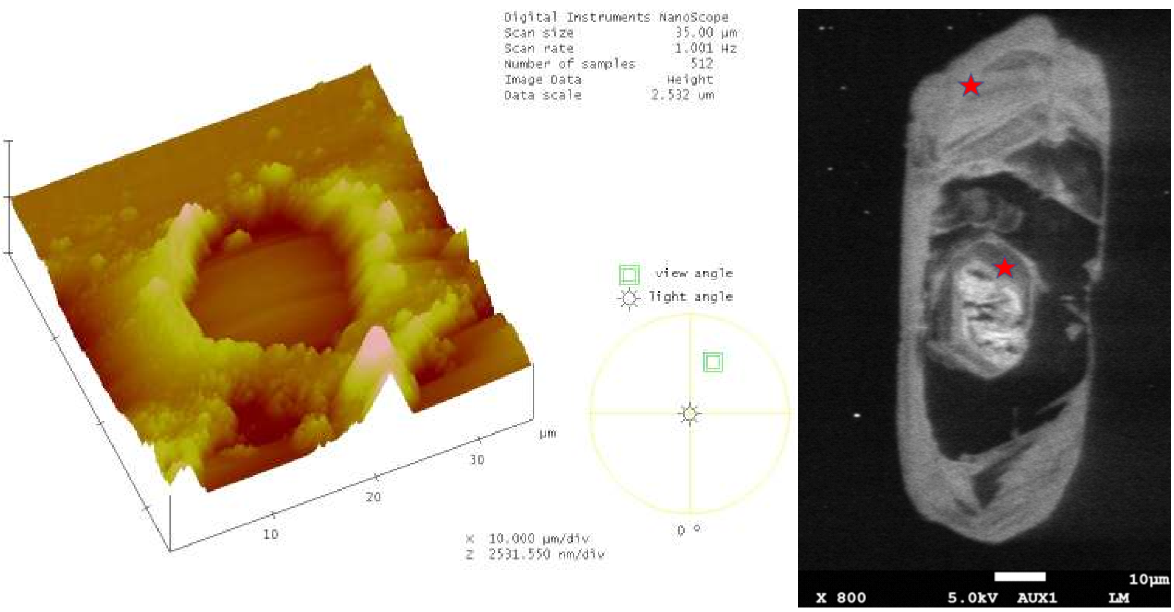


Figure 2: The AFM image of a crater created due to ablation by laser (diameter ~15 um). A typical Zircon grain with points marked (red stars) to be ablated.

Mass calibration is very important to control any shift in the masses of elements and was achieved using a 'tune solution' provided by Thermo Scientific. The mass spectrometer was then coupled with femtosecond laser and was tuned using the NIST standard. The tuning sets up the instrument parameters (such as sample gas, torch position etc.) in such a way that maximizes sensitivity of analyte isotope of interest e.g. ^{238}U, to yield about >1Mcps of intensity at 30µm line scanning of NIST-612 reference glass standard. Several standard reference Zircons such as Plesovice, Temora, 91500, Fish Cannion, and FC1 were used for optimisation of LA-HR-ICPMS at different spot sizes and variable Laser Energy & pulse repetition rate settings. Measurement of $^{207}Pb/^{235}U$ ages of different reference standards showed excellent agreement with the reported values. A number of experiments were performed to check the repeatability of the results.

After this the instrument was ready for measurements. U-Pb dating of 240 detrital zircons from Brahmaputra Basin of a user from IIT Bombay was carried out with the aim to find paleogeographic reconstruction & dynamics of Brahmaputra River system in NE India. This work is still in progress. Of late, we experienced an unusually high background of ^{202}Hg that interferes measurements of radiogenic $^{206\&207}Pb$ isotopes, affecting precision of measurements adversely. It was suspected that these high counts were due to high Hg contamination in the gases used for the analysis. To overcome this problem, an activated charcoal trap was installed in the gas line, but this was not of much help. Following advises of experts, we plan to use high purity gases and installation of specific Hg traps in the gas lines that may help in reducing the background counts of the ^{202}Hg and ^{206}Pb.

The Fs-Laser was also synchronised with the Q-ICPMS and carried out trace and REE elemental analysis of BHVO rock reference standard glass using NIST612 glass as primary standard. The results showed excellent agreement with the reference values. This opened a new avenue and capacity enhancement in which the Fs-Laser can now be used with both the ICP-MS instruments separately or simultaneously using "Split Stream" mode of analysis. This will enable to measure trace elemental abundance of zircon by Q-ICPMS while at the same time the U-Pb dating by HR-ICPMS in a single shot. Further improvement for U-Pb micro-chronology of other accessory minerals (e.g. Monazite, Allanite, Titanite and Apatite) at higher spatial resolutions by HR-ICPMS is in progress.

1.4.2.2 Quadrupole- Inductively Coupled Plasma Mass Spectrometry (Q-ICPMS)

Q-ICPMS procured from Thermo Fisher Scientific (model iCAPQ) became operational in 2018. At regular interval auto tuning is performed in ICP-MS and the sensitivity was checked. Mass calibration is also done in order to maintain its accuracy and sensitivity for precise measurement of trace elements and REE on samples. Femto-second laser was connected with ICP-MS elemental measurement on solid samples. We could generate very high-quality data using Q-ICP-MS and the instrument was regularly used by different users from various Universities and Institutes.

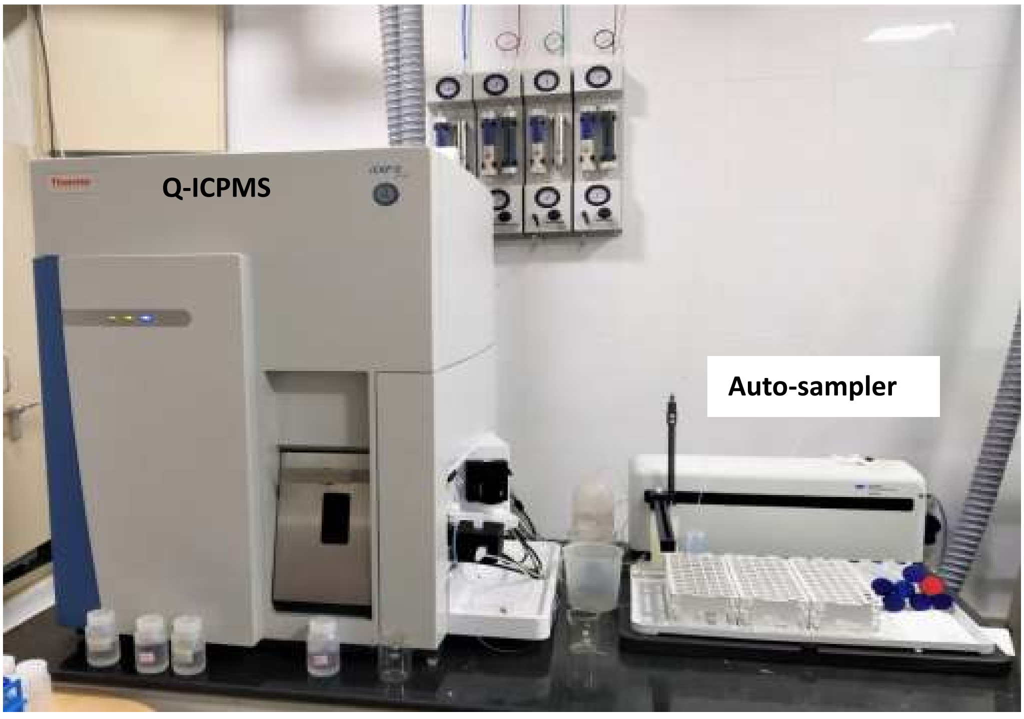


Figure 3: Q-ICPMS installed with Auto-sampler

During April 2019 to February, 2020, trace elements, REE and other elemental analysis of 1583 samples of 22 users from 11 different Universities and Institutes has been done using Q-ICP-MS. The scientific motivations of the studies performed are reconstruction of Paleo-climate and Paleo-Environment and to understand the ground water quality and their effect on human beings (LPU, Punjab, IUAC, Amity University, Delhi University), to understand surface elemental mobilization during rock weathering (JNU, IIT, Guwahati), for provenance study (JNU, Kashmir University), quantification of different metals in aerosols (JNU).

In addition to this, the facility was also used for precise estimation of Be and Al abundance of 4 users as partial requirement for ^{10}Be and ^{26}Al AMS study to estimate denudation rates, climate reconstruction and exposure dating (Kashmir University, BSIP/BHU, IIT Roorkee and IUAC). Q-ICPMS instrument at IUAC is shown in fig. 3.

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

A 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) was procured and the major installation of equipment was achieved. However, the sample studies after the acceptance tests will soon be started. The instrument is shown in fig. 4. 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. For sputtering, vacuum at the sample surface is very important and the analysis chamber has the vacuum of the order of 10^{-10} mbar.

The samples before analysis can be outgassed in the storage chamber having capacity of storing six samples under vacuum of the order of 10^{-8} mbar so that vacuum of the analysis chamber doesn't degrade on loading the sample from storage chamber into it. The loading of the samples from the storage chamber to analysis chamber can be done by just one click from the software. This mass spectrometer has one Electro Static Analyzer (ESA) which does energy filtering followed by one magnet which does the mass separation.

Figure 4: High Resolution Secondary Ion Mass Spectrometer (HR-SIMS)

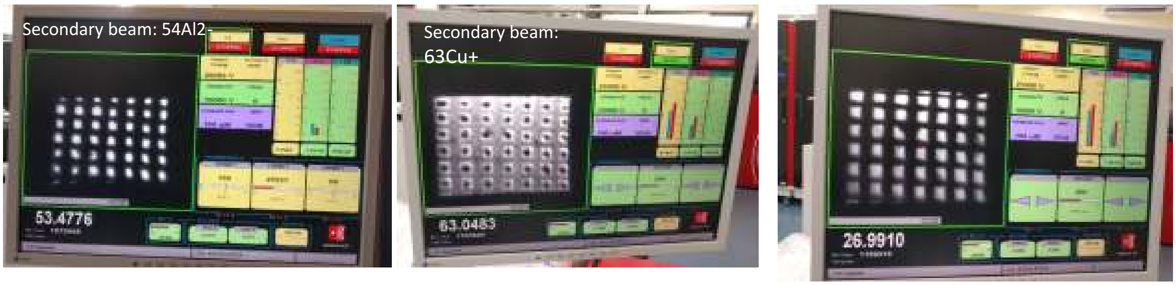


Figure 5: Direct Ion Image of Al/Cu grid using Cs+ as the primary beam and extracting 54Al2-, 63Cu+ and 27Al+ secondary beam

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 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 are some of its applications. Factory Acceptance Test (FAT) of the instrument was performed in the month of October 2019 and the instrument was delivered to IUAC in November. The site for its installation was required to be cleared by CAMECA from any of the vibration and Electro Magnetic Induction (EMI) and finally, room for its installation was prepared. The installation of the instrument was started in February 2020 and its different components were attached to each other followed by required alignments. The instrument was powered and the vacuum pumps were started to achieve required vacuum. In the first attempt itself, the beams could be produced from both the ion sources and the mass spectrometer in the microscope mode was used for direct ion imaging of Cu/Al grid using Cs^+ (from Cs microbeam source) and O^- (from oxygen RF source) primary beams and extracting negative (Al_2^-, AlO^- and O^-) and positive secondary ions ($^{27}Al^+$, $^{63}Cu^+$, $^{65}Cu^+$), respectively. Ion images of the grid extracting $^{54}Al_2^-$, $^{27}Al^+$, $^{63}Cu^+$ as secondary ions are shown in figure 5. The specification tests of the HR-SIMS system are going on and soon the sample studies will be started.

1.4.2.4 Field Emission Scanning Electron Microscope

The Field Emission-Scanning Electron Microscope (FESEM, Model: JEOL JSM 7610F) with the state-of-the-art facilities, namely Energy Dispersive X-ray spectrometers (EDX), Electron Backscatter Diffraction (EBSD) and Cathodoluminescence (CL) attachments, is installed in Inter University Accelerator Centre (IUAC). FE-SEM is used for study of topography and morphology at the micron, sub-micron and nanometre scale. EDX (Model: Ametek Octane Plus) in conjunction with FESEM is a chemical analysis technique used to analyse elements starting from Boron up to Uranium. FESEM enables high spatial resolution observation and easier acquisition of elemental analysis of a material down to sub-micron areas. EBSD (EDAX make) can measure the full crystallographic orientation, texture measurement, grain size distribution, grain boundary shape and phases of crystalline materials, and can be successfully applied in rock forming minerals. CL detector (Centaurus make) coupled with FESEM is used on characterization of growth zoning (i.e., crystal's growth histories) of Zircon and carbonate rocks.

Sputter conductive coatings (either metal or carbon) is a sample preparation instrument for use with FESEM. Our coating instruments include JEC-3000FC (JEOL make) capable of coating platinum and EC-32010CC (JEOL make) carbon rod evaporator shown in figure 6. Electrically conductive coating prevents charging of specimen and causes the enhancement of secondary electrons which further causes the enhancement of signal to noise ratio.

The FESEM facility competently performed throughout the year without any major breakdowns. Rocks, sediments, nuclear targets, biological and material science samples are studied by using FESEM and EDX. Zircon grains for the characterization of growth zoning are studied using CL detector. More than 40 users from all over India have utilized the facility. Few FESEM images taken by JEOL JSM 7610F in IUAC is shown in figure 7.

Figure 6: FESEM image (a) JEOL JSM-7610F, (b) Carbon-rod evaporator and Platinum sputter target

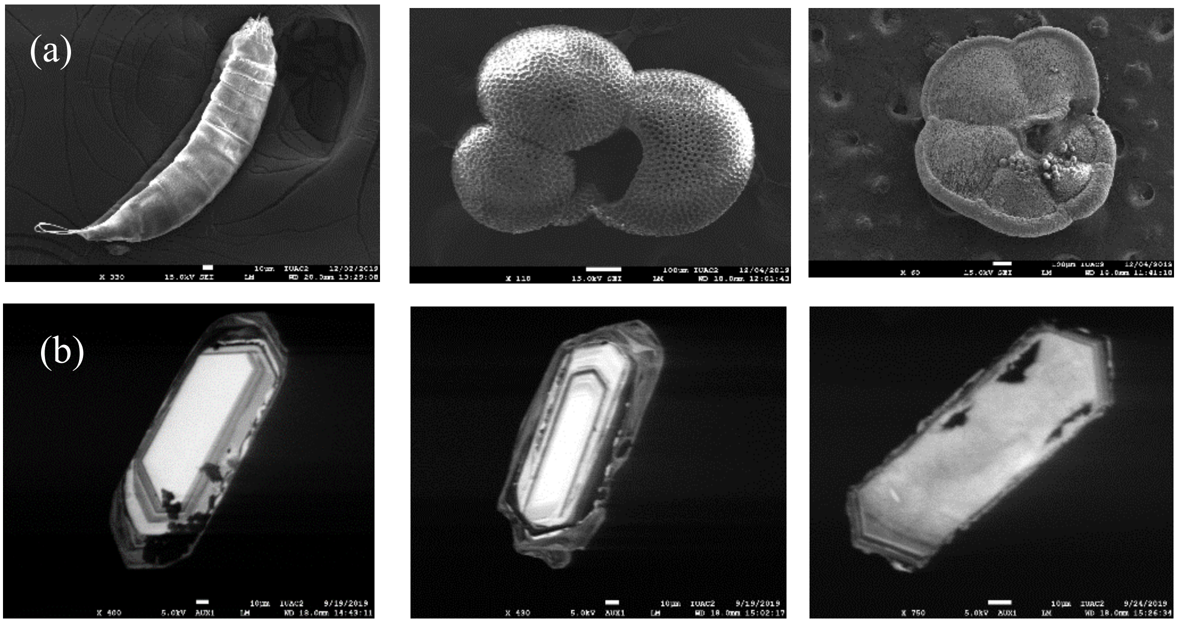


Figure 7: FESEM images taken at IUAC (a) Marine Invertebrates (b) CL image of Zircon grain

1.4.2.5 Wave length Dispersive X-Ray fluorescence

A sequential wavelength dispersive X-rays fluorescence spectrometer along with necessary standards has been installed and has been operational since 2018. A fuse bead machine, pellet press and vibratory cup mill are also installed and utilized for the sample preparation required for XRF measurements. The XRF calibration curves for Granitic and basaltic type of rocks are made and are updated regularly to take care of the change of intensity of x-ray tube over time. This facility is being utilized for non-destructive quantitative analysis of rocks, mineral, sediments for geological applications or for qualitative analysis of different metal complexes. XRF measurements of 966 samples from 23 users from 7 different universities and 2 institution are performed. The analysis helped the users to do geochemical analysis and identification of surface processes of Earth, identifying the ground water potential zones, paleoclimate reconstruction and to identify the chemical effects in different metal-based complexes.

Following maintenances were done in the year (2019-2020):

- The water temperature sensor was not working properly which created problem in turning on the X-Ray tube. This sensor was replaced with a new one.
- The window of the gas flow detector of XRF became porous which raised the gas pressure in the detector. This window was replaced with a new one. The valve adjusting the detector gas flow was also replaced.
- Thrice pellet broke and went inside the spectrometer during the measurement. The spectrometer was opened and pellet was taken out.

All these are shown in figure 8

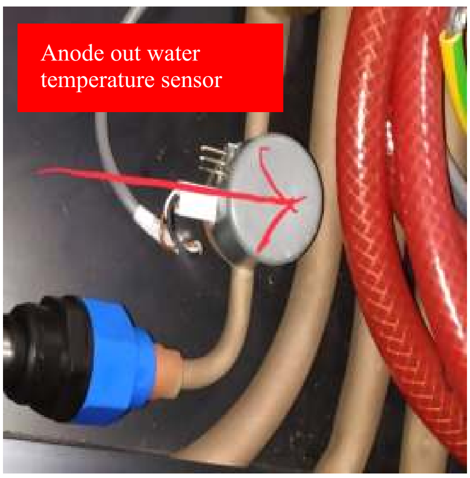
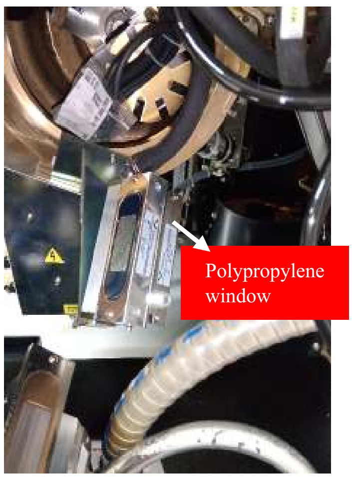
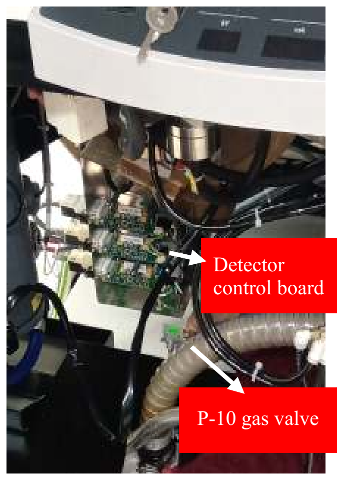


Figure 8: Replacing temperature sensor



Replacing polypropylene window



Replacing P-10 gas valve

1.4.2.6 X-Ray Diffraction

X-ray diffractometer is non-destructive and powerful tool to characterise a crystalline material with minimum sample preparation requirement. Powder X-ray diffraction method is used to determine mineralogy of different geological samples (e.g. clay, sediments etc.) collected from different locations around the country and for phase identification of synthesised crystalline materials. Resulting XRD patterns provide information about the phase lattice structure, absorption, porosity and degree of crystallinity of the minerals/phases identified. X rays diffractometer has been operational since 2017 and being utilized routinely by users for characterization of their samples. 859 samples of 29 users from 15 different universities and 3 institutes, were analysed using XRD. These analyses helped the users to understand the phase formation and transformations under different paleoclimatic changes, depositional environments and Earth surface processes, etc. Figure 9 and 10 show XRD and WD-XRF instruments at IUAC. Figures 10 shows equipment related to the sample preparation for WD-XRF system.

Figure 9: (a) X-Ray diffractometer and (b) WD-X-ray Fluorescence Spectrometer

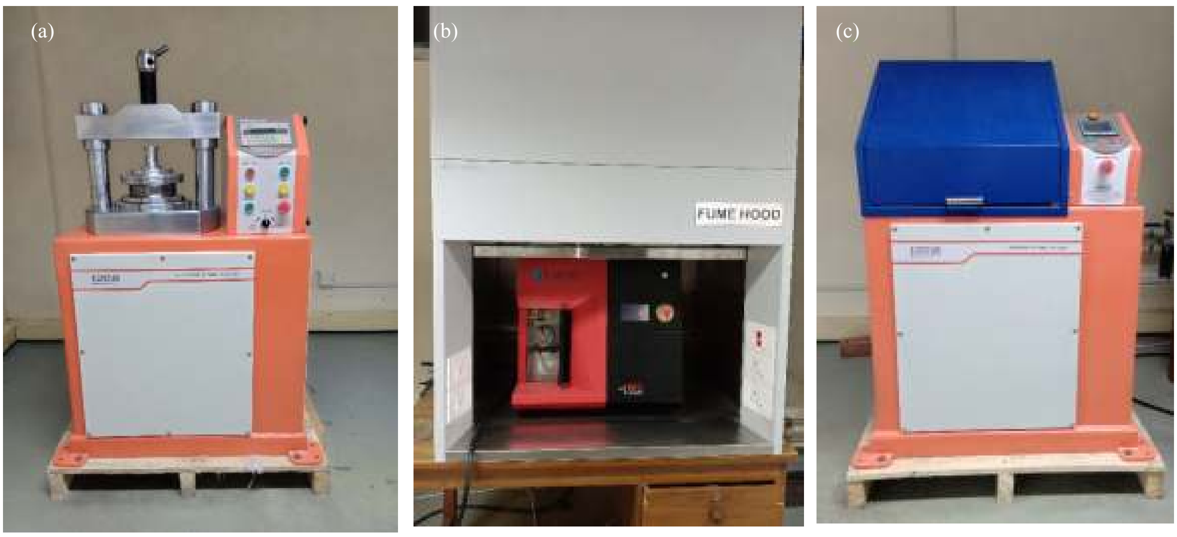


Fig: 10: (a) Pellet Press Machine (b) Fused bead Machine (c) Vibratory cup mill

1.4.2.7 Laboratory magnetic barrier separator

Fig. 11: Magnetic barrier separator at IUAC

Most of the minerals fall under three categories of magnetic properties; ferromagnetic, Paramagnetic and Diamagnetic minerals. Magnetic barrier separator uses magnetic field and gravitational field to separate a particular mineral from the mineral mixture. The magnetic separator has a large electromagnet through which mineral mixtures is passed on an inclined metal plate. By varying the magnetic field value and/or the slope of the metal plate, the minerals of different magnetic properties can be separated from one another. Isodynamic separator placed at IUAC is shown in figure 11. This system was commissioned in June 2019 and about 20 samples have been processed for quartz separation for the purpose of CRN dating.

1.4.2.8 Jaw Crusher, Vibratory disc mill and Sieve shaker

These instruments, shown in fig. 12, were commissioned in July 2019 and are used for physical processing of rock to convert them in required grain sizes of powder. More than 100 rock samples have been processed for the purpose of CRN, ICPMS and XRF analysis.

Jaw Crusher

Rocks must to broken into suitable sizes prior to crushing. Jaw Crusher is used for crushing large size samples (< 9 cm) to smaller sizes (~ 2 mm). Rock size bigger than 9 cm are broken into small pieces using hammer or any other suitable instrument.

Vibratory Disc Mill

Vibratory Disc mill further reduces sample size by grinding it between two cylindrical discs mounted on a circular and horizontal vibratory platform. The feed size of this unit is < 15 mm, which results in output of fine powder of sizes < 20 µm.

Sieve shaker

Sieve shaker contains stack of sieves of different pore sizes. The Sieve stack is mounted on the vibratory platform, where the speed and duration of vibration can be adjusted. Sieves of various mesh sizes are used for sieving purposes.

Figure 12: Jaw crusher, vibratory disc mill and sieve shaker

1.5 LOW ENERGY ION BEAM FACILITY (LEIBF)

Pravin Kumar and Ambuj Tripathi

The all-permanent-magnet 10 GHz Electron Cyclotron Resonance Ion Source (ECRIS) based Low Energy Ion Beam Facility (LEIBF) [1, 2] has been in continued service of delivering high flux gaseous beams over a broad range of energy to the user community. The ion source along with its peripheral components, installed on a 400 kV platform, and the complete layout of the unique low energy accelerator including its dedicated three beam lines (at 75^0, 90^0 and 105^0) are shown in figures 1 (a) and 1 (b), respectively. Total 16 users from various universities and research institutes availed the beam time during July 2019 to December 2019. The ion beams of H, He, N, O, Ar, Kr and Xe were mainly delivered for the experiments. The maximum energy for proton beam was limited to 350 keV and accordingly, the energy enhancement in heavy beams was employed by selecting the appropriate charge states at the time of analysis by the high resolution dipole magnet.

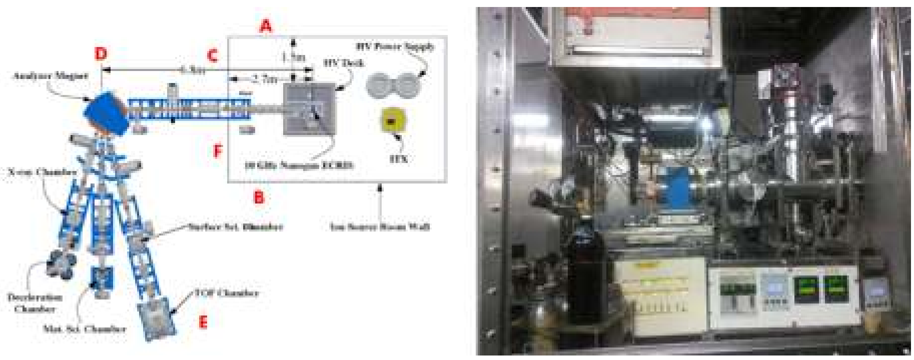


Fig. 1 (a; Left): Layout of LEIBF (top view), Fig. 1(b; Right) All-permanent-magnet 10 GHz ECRIS along with its peripheral electronics on HV platform

In addition to user's support, in-house research programmes on systematic studies of surface patterning by ion beams and investigations of room temperature ferromagnetism in oxide semiconductors were also pursued by conducting novel experiments. Special efforts were put to gain better understanding of still unrevealed gas mixing and anomalous effects [3] in ECR plasma. In continuation of earlier studies with Xe and Kr plasmas, we made some interesting measurements with Ne plasma. The gas mixing effects with O_2 on higher charge states of Ne has been observed. The pure natural Ne plasma shows clear evidence of anomalous effects in intensities and with O2 gas mixing; it gets weakened as shown in figure 2.

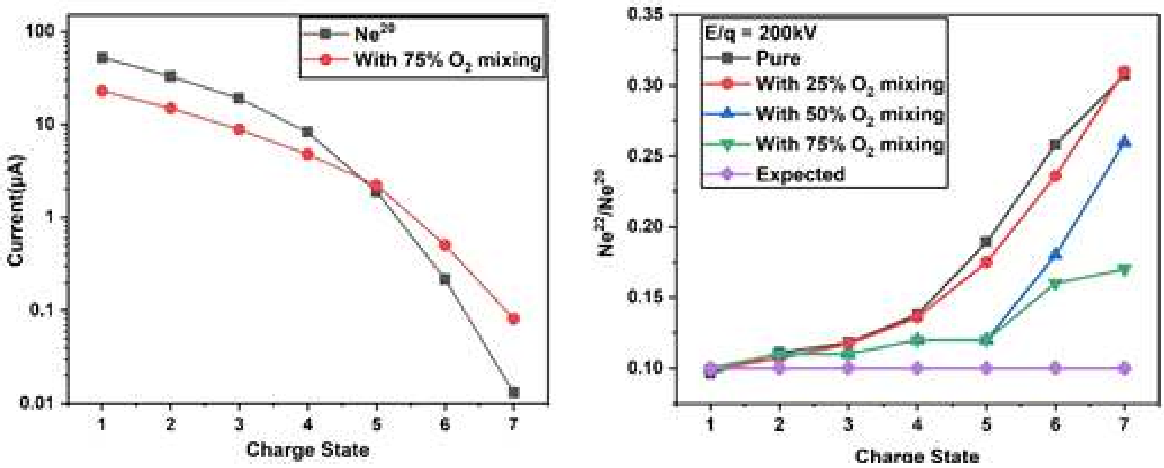


Fig. 2 (a; Left): Gas mixing effect in Ne plasma, Fig. 2(b; Right) Signature of anomalous effect in Ne plasma

With several beams of different parameters, a radiation survey (area monitoring) was done by health physics group to ensure the safety of staff and users working in the beam hall of LEIBF and closely located other labs. The design of a proper shielding structure was worked out to its installation at appropriate places in order to run the LEIBF in continuous operation.

Acknowledgement:

We sincerely thank the colleagues from the support labs viz. vacuum, electronics, beam transport, workshop, MG-1 & II etc. for their help in timely maintenance of the facility. The association of Dr C P Safvan with LEIBF for promoting atomic and molecular physics research programs is highly acknowledged. Sincere thanks are due to Ms Punita Tripathi (JRF), Dr Sushant Singh (RA), Mr Amit Kumar and Mr Krishan Kant Pal for ion source operation and recording the beam intensities.

References:

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1.6 TABLETOP ACCELERATORS

Raj Kumar and C P Safvan

1.6.1 Usage of Tabletop Accelerators

IUAC has designed, developed & installed 30 kV & 60 kV Tabletop Accelerators in-house . Both of them have been in regular use during last year. The following table indicates the usage of the accelerators during last year.

	60 kV Tabletop Accelerator	30 kV Tabletop Accelerator
No. of runs	5	10
No. of users	5	7
No. of samples implanted	49	93
Beams provided	H^+, $H2^+$, He^+, $He2^+$	
	N^+, S^+, Ar^+, O^+	
Energy range	25 to 96 keV	3.5 to 25 keV

1.6.2 Collaborations for Setting-up Similar Accelerators in Other Institutes

IUAC is helping by providing all design details, fabrication drawings, all technical knowhow to the following institutes for setting-up similar accelerators.

1. Manipal Centre for Natural Sciences, Manipal University, Manipal 50 kV Tabletop Accelerator has been set-up at Manipal University with the help of IUAC.

2. Amity University, NOIDA

   DST funded 50 kV Tabletop Accelerator is being set up at Amity University, NOIDA with support from IUAC. It is in the final stage of completion. All components have been fabricated and procured and installation is in progress.

3. IIT Roorkee

   Request has been received from IIT Roorkee and technical details have been shared. Design of the ion source has been explained. IIT Roorkee plans to first have a similar system, then work on improving the extraction using multi-electrode system. They are designing a Wein filter to replace the analyzing magnet.

   Various items are being procured and fabricated with support from IUAC.