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अन्तर–विश्वविद्यालय त्वरक केन्द्र
Inter-University Accelerator Centre

(विश्वविद्यालय अनुदान आयोग का स्वायत्त अंतराविश्वविद्यालय केन्द्र)

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Installation and Testing of second accelerating module of LINAC

Figure 1. Three accelerating modules and the second cryostats with eight resonators of LINAC

The complete linear accelerator (LINAC) of Inter University Accelerator Centre (IUAC) will consist of five cryostats, the first one acting as superbuncher (SB) consists of a single quarter wave resonator (QWR), the next three LINAC cryomodules house eight QWRs each, and the last one has two QWRs used as rebuncher (RB).

Last year, ion beams in the range ^{12}C to ^{107}Ag from Pelletron were further accelerated by the first LINAC module and delivered to conduct experiments in Nuclear Physics and Material Science. During the last six months another eight niobium resonators were installed in the LINAC cryostat-2 and after off-line cold tests, beam acceleration was done through two modules. During the beam acceleration, all sixteen resonators of cryostat 1 and 2 were used along with one resonator each operated

Table 1. The beam species and their total energies delivered for experiments

Beam	Pell. energy (MeV)	LINAC energy gain (MeV)	Total energy (MeV)	Beam Line
$^{19}F^{+7}$	100	37	137	NAND
$^{28}Si^{+11}$	130	60	190	LINAC Scattering Chamber
		56	186	HYRA
$^{31}P^{+11}$	130	58	188	HYRA

in superbuncher and rebuncher. During the period of beam acceleration extending for more than a month, three different ion beam species: ^{19}F, ^{28}Si and ^{31}P were accelerated and beam was delivered in the beam line of HYbrid Recoil mass Analyzer (HYRA) and National Array of Neutron Detectors (NAND). The results of the beam acceleration, in brief, are given in Table 1.

To ensure safe operation of LINAC with minimum human intervention, quite a few steps were taken in the past to automate the LINAC operation. The different developments in the automation of LINAC operation are as follows:

- Remote control of the phase/amplitude locking of a superconducting resonator was implemented.
- During the phase locking of the resonator, the forward power going to a resonator was monitored in a module and displayed in the control console kept at the control room and other places.
- In the event of the resonator going out of phase lock, RF power going to the resonator from the amplifier reaches its maximum value which may damage the power cables. A computer code in python language was written to monitor the status of the phase lock condition and to sense the power going into the resonators.
- The movement of the drive coupler to feed the power into a resonator was controlled by computer with a position read back of the power coupler.

At present, the installation work of the remaining eight resonators in the last accelerating module (number-3 in figure 1) of LINAC is going on. After that, offline cold tests are planned to validate the performances of the resonators installed in LINAC-3. The operation of the complete LINAC and the delivery of the ion beam for scheduled experiments are expected to start at the second quarter of next year.

Design Validation of IH Type Drift Tube Resonator

The High Current Injector (HCI) project at IUAC would use a Radio Frequency Quadrupole (RFQ), Drift Tube LINAC (DTL) and low beta superconducting cavities to accelerate heavy ions having $A/q \leq 6$, from the high temperature superconducting electron cyclotron resonance ion source (HTS-ECRIS called PKDELIS) to the existing superconducting linear accelerator (SC LINAC).

Complete design validation has been done on a full scale prototype DTL resonator. Low level RF tests using bead pull technique were carried out. These tests validated the design frequency and electric field profile along the beam axis (Fig.2).

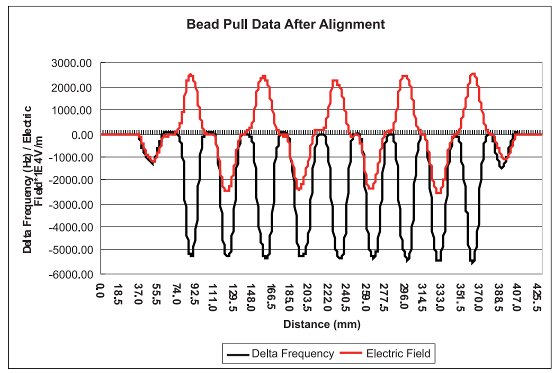


Figure 2

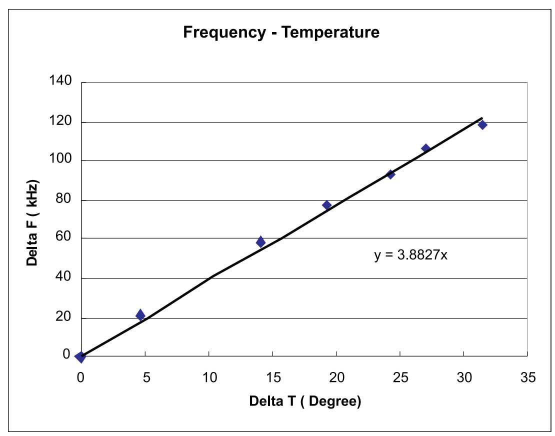


Figure 3

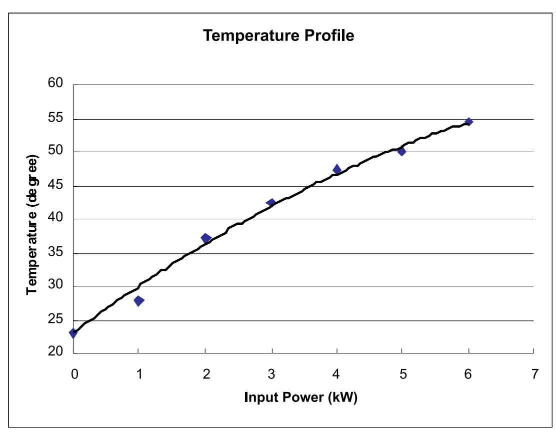


Figure 4

High power RF tests have also been completed successfully. Prototype resonator has been tested upto 6 kW input power. Total duration of high power test was ~ 100 hrs. Frequency and temperature variation has been measured (Fig.3). These tests have validated the complete resonator design parameters, power coupler and efficiency of water cooling. Figure 4 shows temperature at ridge base at different input power. Design modification is on to further improve the cooling efficiency near ridge base.

PARAS (Pelletron Accelerator RBS-AMS Systems)

Figure 5. RBS facility at IUAC

RBS facility at IUAC (Fig. 5) was installed in the month of Dec 2010 and is operational since then. The facility is equipped with

a) alphatross ion source producing negatively charged He and H beams.

b) 1.7MV 5SDH-2 Pelletron accelerator and

c) Charles Evans and Associate make 4 – axis goniometer (model name RBS-400)

Energy of helium beam backscattered from samples is measured by surface PIPS detector.

Measurements on over 1500 samples have been performed. Majority of these measurements were to analyze the sample pre and post irradiation, to measure the thickness of thin films and other impurities in the sample. These measurements were done with 2 MeV, He^+ ion beam. For determining oxygen stoichiometry in particular samples, oxygen resonance mode of RBS was utilised in which, samples were analysed with 3.040 to 3.050 MeV He^+ ions. Channeling measurements for some samples were also carried out at room temperature.

In the last 10 months, maintenance of the ion source was done twice. Average time between maintenance of the ion source is approximately 3 – 4 months, after which, it has to be opened, thoroughly cleaned, installed back and Rubidium has to be loaded.

There was only one major breakdown, when the Generating Voltmeter (GVM), which reads the high voltage of terminals of the accelerator, stopped functioning. GVM was removed and after inspection its bearing had to be replaced. After installation, terminal voltage was calibrated by observing resonance of helium on oxygen at 3.040 MeV.

New Low Energy Ion Beam Facility

The new Low Energy Ion Beam Facility (LEIBF) using fully permanent magnet ECR ion source (Nanogan) has been installed (Fig. 6) in Material Science Building of IUAC. The accelerator consists of an ECR ion source, 400 kV accelerating column and an analysing-cum switching magnet with three beam ports at 75, 90 and 105 degrees. The complete ion optics from ECR ion source to the target has been simulated using TRANSPORT and GICOSY ion optics codes. The ions from the ECR source are typically extracted at 15 kV which are further accelerated by 400 kV accelerating column. The analysing cum switching magnet has been designed to analyse different beams and to switch in a particular beam line. It is a H shaped dipole magnet having pole gap of 65 mm, maximum magnetic field of 1.5 T and radius of 529 mm for 90 degree bend. The entrance and exit edge angles for three beam lines have been optimized to obtain double focus in all beam lines. The beam is further transported to target locations using electrostatic quadrupole triplet. The installed facility is shown in fig 6. The system has been fully tested. Typical X and Y beam profiles are shown in fig 7. A workshop was organized in October for presentation of beam time from users. About fifty proposals have been accepted in the workshop.

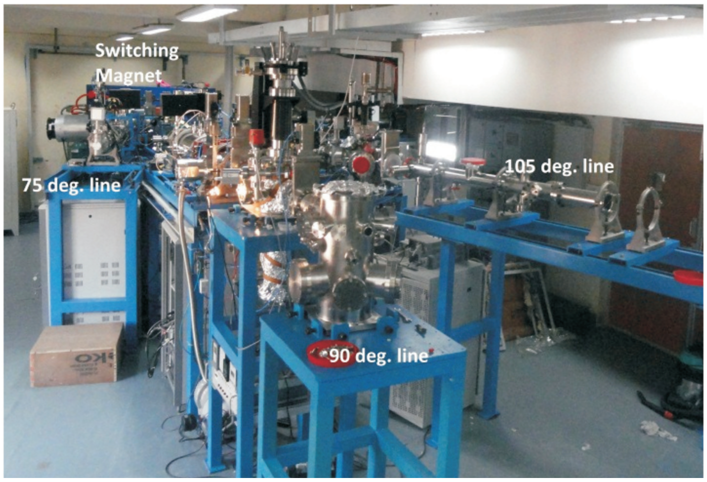


Figure 6: Installed LEIB facility

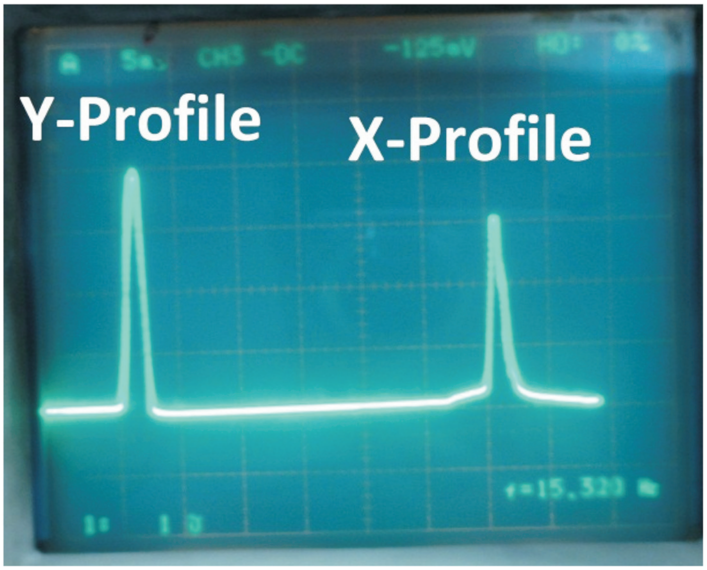


Figure 7: Beam Profiles in 75° beam line at the image point of anlyzing magnet

Neutron Array Project at IUAC

Department of Science and Technology (DST) has given financial support for setting up a large neutron array at IUAC. The array consisting of 100 liquid scintillators along with a high efficiency fission/charged particle detector array will be used for neutron-charged particle coincidence measurements using heavy ion beams from LINAC facility at IUAC. Once completed this facility will be the largest neutron array in our country. This advanced detector array with high efficiency and good time resolution would be very helpful for number of researchers from universities and institutions to explore the various aspects of heavy ion reaction mechanism.

The project will be completed in two phases, with the first phase consisting of 50 detectors and its pulse processing electronics. The detectors will be NE213 compatible liquid scintillator of type BC501A, 5″x5″ cylindrical size coupled to 5″ photomultiplier tube R4144 from Hamamatsu. The detectors will be mounted at 175 cm radial distance from the target. The targets and fission detectors will be housed in 100 cm diameter spherical vacuum chamber. 100 neutron detectors will be mounted on a 'Geodesic Dome' mechanical structure at 175 cm radius as shown in fig. 8. Currently the work on the development of readout electronics and mechanical mounting structure is in progress.

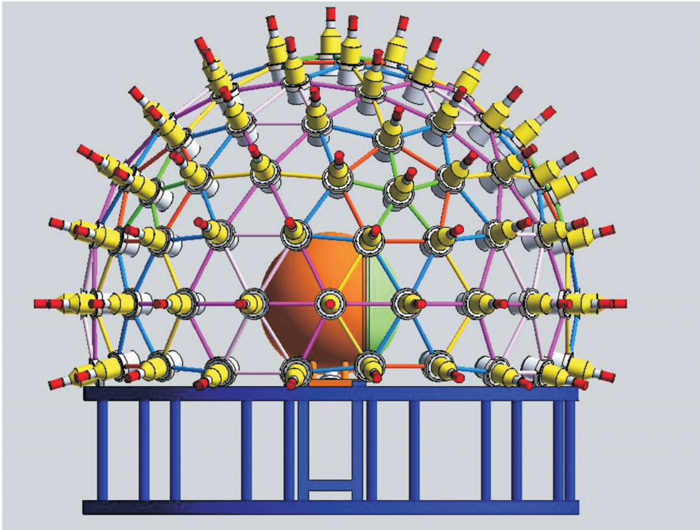


Figure 8: Geodesic dome structure for proposed Neutron Detector Array

Status of Materials Science

Ion beam produced nanoripples have been used as template to grow aligned Au nanodots by glancing angle deposition and the conditions for the same are optimized by experiments. The process of growth of aligned nanodots is simulated by Kinetic Monte Carlo simulation

(Nanotechnology 22, 235305, 2011). Fig. 9(a) and 9(b) show the aligned Au nanoparticles and random Au nanoparticles respectively. The former is obtained by glancing angle deposition on nanoripples template synthesized by 1.5 keV atom beam. In pursuit of role of swift heavy ion beam in engineering the shape of embedded nanoparticles in silica matrix, the Ni nanoparticles in silica matrix are shown to undergo shape transformation from spherical to elongated one along the beam direction (Nanoscale Research Letters 6, 155, 2011).

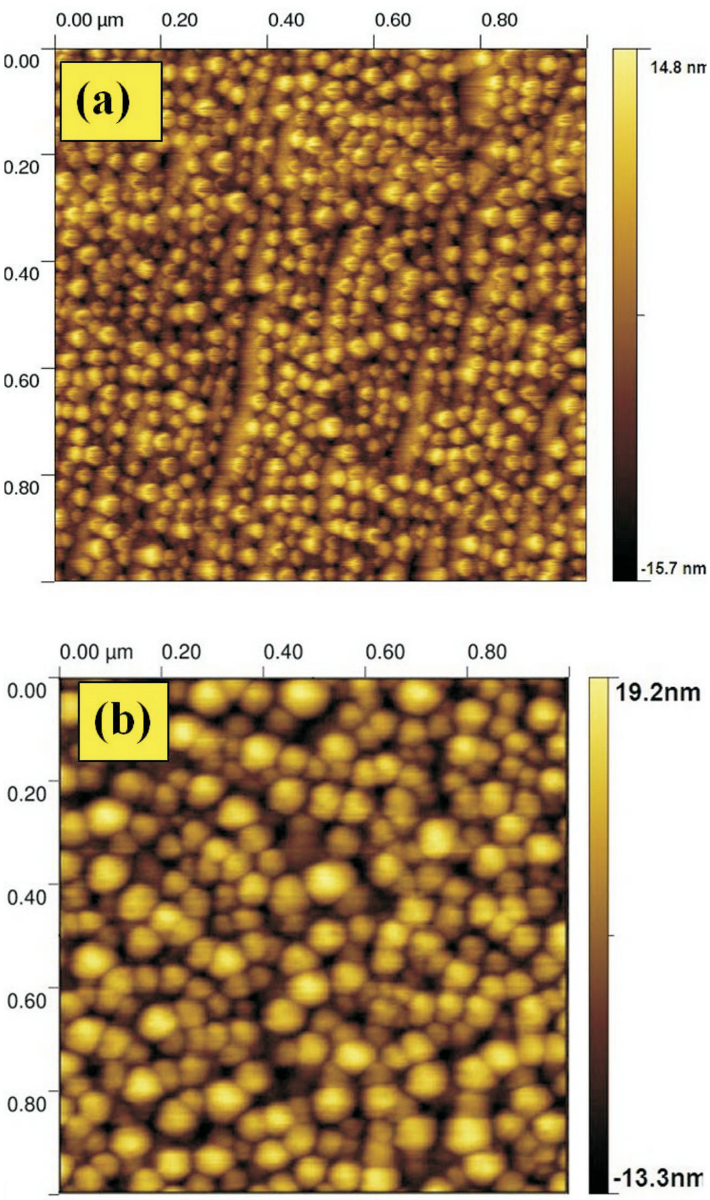


Figure 9: Figure (a) shows the aligned Au nanodots whereas figure (b) shows random Au nanodots

Workshops /Schools/Acquaintance Programs (April – October, 2011)

A two-day workshop on **High Performance Computing** was organized as part of the training and outreach program of the IUAC High performance Computing (HPC) facility in May 2011. The focus for this workshop was two-fold: to get together prospective nuclear physics users to introduce them to the facility and define areas where HPC could be productively used in nuclear physics calculations; and to offer existing users of the facility a platform to discuss the work done using the facility. Fourteen talks were presented, and forty faculty members and students from twelve institutions participated. Nuclear physics talks explored the application of large scale computing to mass formulae, shell models, and astrophysics. Users of the facility presented work and proposals in areas ranging from novel nano-materials and drug discovery to DNA unzipping and genome sequencing.

Accelerator Mass Spectrometry (AMS) and associated facilities at IUAC are completely operational. A few research projects are successfully completed and many are being studied. In order to generate awareness and to further enhance the research activities, two workshops on AMS were organized in the year 2011. The first international workshop was organized jointly by Indian Society of Mass Spectrometry and IUAC in the month of April 2011. There were many interdisciplinary participants from India and abroad. The talks were delivered by eminent researchers in the field. There was another one day workshop on Sept. 15, 2011 organized by IUAC to broadly discuss the applications of AMS among Indian scientific community. There were many invited talks focusing on the utilization of ^{10}Be, ^{26}Al and ^{14}C in various domains of science. There was also discussion about development of other AMS related facilities to further augment existing facilities at IUAC.

A conference on **Nanostructuring with Ion Beams**, co-organized by IUAC and University of Allahabad was held at University of Allahabad on Oct 17-19, 2011. There were 19 invited, 13 oral and 47 poster presentations. Three invited speakers; Prof. Mark

Bradley, Dr. J.C. Pivin and Dr. S. Dhar were from USA, France and Singapore respectively. There were invited presentations related to theoretical aspects by Prof. Bradley, Prof. B.K. Agarwal, Allahabad University and Prof. P. Sen, HRI Allahabad. The conference was inaugurated by Dr Amit Roy (Director IUAC) and presidential address was given by Prof A.K. Singh (VC, University of Allahabad). The conference had focused discussions on applications of ion beams with different energy ranges for synthesis and modifications of nanostructures. The chairman and convener of conference were Dr. D.K. Avasthi, IUAC and Prof. A.C. Pandey, Allahabad University, respectively.

A two days workshop entitled **Materials science and atomic & molecular physics experiments using low energy ion beam facility** (LEIBF) was organized on 21-22 October, 2011 at IUAC. The aim of this workshop was to enhance the number of potential users of LEIBF, which has turned out to be a world class facility with new features (400 kV platform, new beam hall, three dedicated beam lines, better ion optics, high vacuum experimental chamber etc.). About 70 research proposals were received for beam time request and 52 proposals were discussed in the workshop. Large numbers of proposals were based on the current research topics and highly appreciated by the reviewers. Beam time allocation to all the discussed proposals has been done. Some of users have already completed their quota of beam time. The facility, LEIBF, is opened to all researchers from universities/institutes, IITs in India and abroad.

A one day **IUAC acquaintance program** was held at department of Physics, HP University **Shimla** on 14th June, 2011, which was inaugurated by the Vice Chancellor of the university. Lectures on the materials science facilities and research were delivered by Dr. Fouran Singh and Prof. Mahavir Singh; while the lectures on the nuclear physics facilities and research were given by Mr. Subir Nath and Prof. Devinder Mehta from Punjab University, Chandigarh. A large number of faculties and students from the nearby universities and colleges participated in the program. At the end of the program a panel discussion was arranged to respond to the various queries of the students and faculties about the facilities and their utilities by the university users.

Another one day **IUAC acquaintance program** was held at Department of Physics, North Orissa University, **Baripada** on Sept. 16, 2011. Lectures on Accelerators and Materials science were delivered by Dr. D. Kabiraj, IUAC. Dr. Rakesh Kumar of IUAC delivered lecture on Nuclear and Atomic Physics. Prof. N.C. Mishra of Utkal University was invited to deliver lecture on their research work using IUAC ion beam facilities. Students of the University and faculty members of different Colleges participated in the program.

Summer Project for B.Sc. Physics students was conducted successfully. Good response was received from different colleges in Delhi and outside Delhi. Fifteen students participated in fifteen different projects conducted by IUAC academic staff.

Teaching Lab. activities

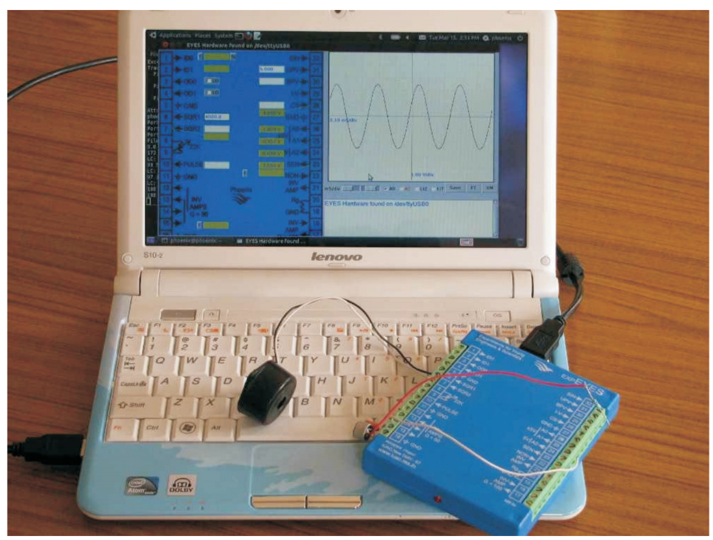


Figure 10: The expEYES device

A new device, named expEYES, has been developed to support teaching experimental science. It is a portable, expandable and affordable science laboratory, supporting a wide range of experiments from high school to post graduate level. It combines the power available under Python for doing scientific computation and data visualization, with control and data acquisition hardware device that can communicate to Python over the USB port. Mathematical analysis of experimental data and the GUI are done using modules like Scipy, Matplotlib and Tkinter. GUI programs are available for around fifty experiments that are documented in a user manual. The programmer's manual helps in developing new experiments using the Python library. ExpEYES has a resolution of 0.1% for analog signals and one microsecond for time interval measurements. It can change the way in which science and engineering is taught and encourages the concept of learning by exploring. For more details one may visit http://expeyes.in.

Forthcoming Programmes

FIG12: The Conference **Frontiers in Gamma-Ray Spectroscopy 2012** devoted to gamma spectroscopy, is to be held at IUAC during March 5-7, 2012. The focus of FIG12 will be on the most recent experimental and theoretical advances in the field of nuclear gamma spectroscopy. Additionally, discussion on subjects of common interest with other fields will be encouraged.

SHIMEC 2012: International Conference on **Swift Heavy Ions in Materials Engineering and Characterization** (SHIMEC 2012) will be organized from 9th to 12th October 2012. This is in continuation of SHIMEC series, the last one of which was held in October 2010. The conference will be preceded by an international school on **Ion Beams in Materials Science** which will be held from 3rd to 8th October 2012.

FUSION14 : The next International Conference on Fusion reactions around Coulomb barrier (FUSION14), the sixth in the series, will be conducted at New Delhi with IUAC taking the lead. The decision was taken at the International Advisory committee meeting during FUSION11 conference held at St. Malo, France.

Status of 15 UD Pelletron (April 1 to October 31, 2011)

Operation of Pelletron was quite satisfactory for the period 1st April 2011 to 31st October 2011 without any scheduled or unscheduled tank opening maintenance of the Pelletron accelerator. A few problems encountered during its operation were rectified during short maintenance period.

After tank opening maintenance, beam runs for users started from 10th February 2011 onwards. Instability was noticed in beam current due to instability in terminal voltage caused by fluctuation of chain 2 charging current as soon as it reached ~ 18 micro amps. It was found that some discharge path had developed in unit #22 which caused the problem. This unit was shorted and thereafter beam runs were quite stable and smooth up to October 2011. The charging power supply was replaced once in June as the faulty power supply resulted in improper charging of terminal.

During six months of MC-SNICS operation, the source was opened three times, twice for break down maintenance and once for routine maintenance. During routine maintenance in May, the ionizer and other ceramic components were replaced. A new Cs ampule (5 gm) was also loaded in the source.

In August 2011, the source started giving problem after a long run of Sulphur beam. The source was opened and it was observed that a large number of flakes were shorting the cathode wheel, the filament body and the cesium focus lens. The cesium focus lens and the filament cover were replaced to solve the problem.

Another breakdown of source was encountered in September 2011. The cesium focus electrode was not holding the potential. This also happened after the operation of source for the production of Sulphur beam of high current. The source was opened again and cleaned to solve the problem and a few components were also replaced.

Some minor electronics related problems were also encountered in the source during this period of operation. The extractor power supply was replaced once. Some of the General Purpose (GP) tube resistances were also replaced as they got damaged probably due to moisture. Maintenance work on dehumidifier was also carried out which improved the humidity level.

Maximum terminal voltage achieved during high voltage conditioning was 13.3 MV. 90 MeV of ^{12}C beam was delivered to user at the maximum terminal potential of 12.81 MV and 20 MeV of ^{6}Li beam was delivered to user at the minimum terminal potential of 6.61 MV.

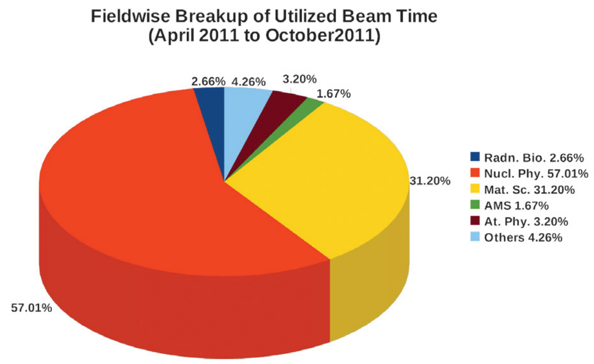
Out of total beam time of 3157 hours, 1089 hours of beam time was used for pulsed beam runs using multi harmonic buncher (MHB) along with low energy chopper and traveling wave deflector. 701 hours of total pulsed beam time was delivered to users, after boosting beam energies using LINAC. Energies of ^{19}F, ^{28}Si, ^{30}Si and ^{31}P were boosted by using LINAC.

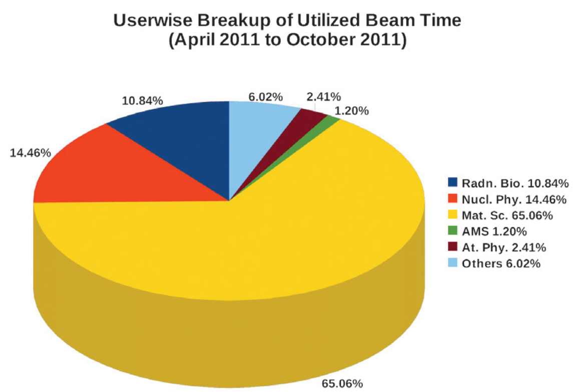
Only ^{12}C beam was bunched and delivered to users for different experiments for the remaining 388 hours of pulsed beam. All the pulsed beam runs were quite stable.

Statistical Summary

Total Chain Hours =	5095 Hrs.
Beam utilization time =	3157 Hrs.
Beam change time =	9 Hrs.
Machine Breakdown time =	75 Hrs.
Machine scheduled maintenance =	0 Hrs.
Accelerator conditioning =	157 Hrs.
Beam tuning time =	204 Hrs.
Experimental setup time =	40 Hrs.

The uptime of machine for this period was 98.53%. The beam utilization time was 61.96%.





User List: April to October, 2011

Sr. No.	University / Institute / College	Shift Utilized
1.	Allahabad University	5
2.	Aligarh Muslim University	13
3.	Anna University	5
4.	BAMU, Aurangabad	1
5.	Bangalore University	1
6.	BARC	16
7.	Bharathiar University	3
8.	Bharathidasan University	2
9.	Banaras Hindu University	6
10.	Calicut University	16
11.	Cochin University	2
12.	CSNSM, Orsay, France	2
13.	DAV College Kanpur	2
14.	DBAM University	4
15.	Delhi University	28
16.	Guru Nanak Dev University	8
17.	IIT, Delhi	9
18.	IIT, Kharagpur	2
19.	IIT, Rorkee	2
20.	ISRO, Bangalore	8
21.	ISRO, Thiruvanathpuram	2
22.	IUAC	91
23.	Kalyani University	2
24.	Kongunadu College	5
25.	Manipur University	2
26.	MMH College, Ghaziabad	10
27.	Mysore University	3
28.	NIT, Kurukshetra	4
29.	NIT, Raurkela	1
30.	Padova University	3
31.	Punjab University	77
32.	Rajasthan University	2
33.	SINP, Kolkata	12
34.	Srissat, Aurangabad	1
35.	Tezpur University	8
36.	TIFR, Mumbai	31
37.	Tumkur University	1
38.	University PES, Dehradun	1
39.	Utkal University	4
40.	WBUT, Kolkata	1