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Inter-University Accelerator Centre
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## Status of Superconducting Linear Accelerator

The first module of booster Superconducting Linear Accelerator is at the final stage of installation and commissioning. Last year, first acceleration of $^{28}Si^{+7}$ beam from Tandem accelerator was achieved by using five resonators of the first linac module.

The lower energy gain in this test compared to what was expected from the design value of the resonator was due to a metal coating (predominantly zinc) on the inside surface of the power coupling port. The coating was formed by evaporation from the rack mechanism of the drive coupler due to operation of the resonator at 200-300 watts of forward RF power. In order to alleviate this problem, several measures were taken viz., modification of the movement and cooling mechanism of the drive coupler and damping of the vibration of the resonator.

A new drive coupler without having any rack and pinion movement mechanism was designed, fabricated and tested with a number of superconducting resonators. This coupler has the provision of liquid nitrogen cooling. During the recent cold tests of the new drive coupler with resonators, no coating was observed and the performance

**Fig 1. Eight niobium resonators and a solenoid are installed prior to first beam acceleration**

of the resonator did not deteriorate over a long duration of locking period.

Due to presence of large microphonic vibration in the ambience of linac cryostat, the excursion of the resonator frequency around the locked frequency of the master oscillator (97.000 MHz) was found to be ~ ± 50 Hz, necessitating RF power of ~ 200-300 watts to lock the resonator in over coupled mode at the time of beam test. To reduce the requirement of RF power, a novel, low cost technique of damping the mechanical mode of the resonator has been evolved and tested with SC resonators. Ordinary stainless steel balls of diameter 4.0 mm were inserted in the central conductor so that they stay at the end of the drift tube as shown in fig.2. The dynamic friction between the balls and the niobium surface, results in damping of the oscillations of the central conductor and the amplitude as well as the decay time of the vibration of the mechanical mode is reduced drastically.

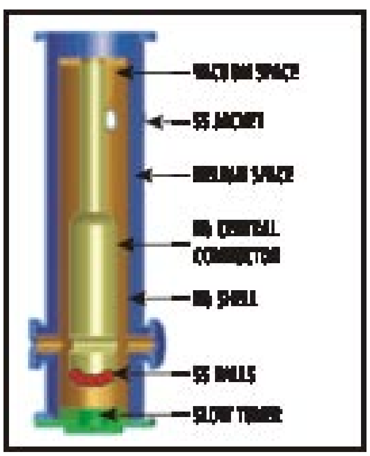


**Fig. 2. Cross-sectional view of a resonator along with a few SS-balls**

On optimizing the number of SS balls, a reduction of ~ 50% in the overall frequency excursion of the resonator ($\Delta f$) around its mean frequency had been measured in repeated experiments with different resonators and the result is shown in fig.3.

This has resulted in the reduction of RF power of at least 50% with the SS-balls as damper inside the central conductor. During a recent cold test in linac

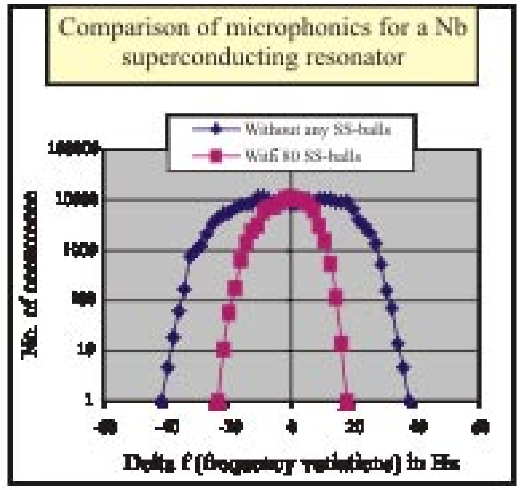


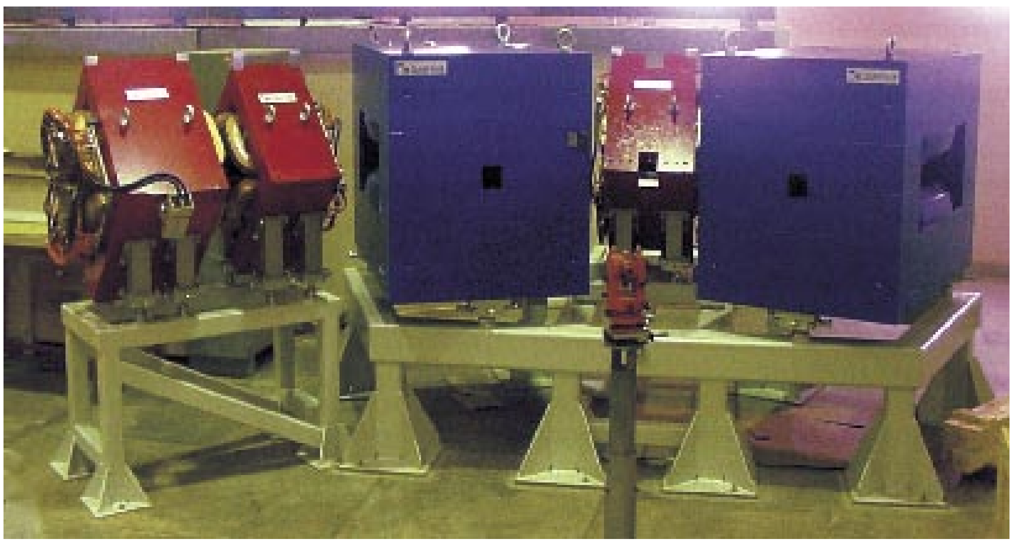

**Fig.3. Frequency excursion of a superconducting resonator with and without damper**

cryostat, a resonator with SS balls was locked at a field of 5.1 MV/m at a forward power of ~ 78 watts from RF amplifier.

With these developments, eight resonators are going to be installed in the linac cryostat and the beam acceleration through them is planned by the end of this year.

## HYbrid Recoil mass Analyzer (HYRA)

The first stage magnetic dipoles (MD1 and MD2), quadrupoles (Q3, Q4 and Q5), the associated support structures, chambers and the power supplies are ready. The dipoles and quadrupoles have been field mapped extensively and the relevant parameters extracted from them have been found to be very close to the design values. This stage has been aligned with Q5 and Q4 at the front end in place of Q1 and Q2 which are planned to be superconducting, super-ferric type and are under development. MD1 chamber has been provided with Tantalum linings backed by water-cooled copper channels on either side of central trajectory to dump the beam in both the gas-filled mode and vacuum mode operation of HYRA. Q3 is provided with option to move sideways to make way for an intermediate focal plane position which will be used in gas-filled mode to select very heavy nuclei of low energies. This results in reduced path length in gas-filled region thereby increasing the transmission efficiency while reducing the dispersion / selectivity. The reproducibility of Q3 positioning after such movement has been tested. The utilities (processed water for cooling magnets and power supplies, electrical connections, compressed air, etc.) are expected to be ready by November end. As the Indian National Gamma Array (INGA) is also funded recently, the work on the beam-line and target chamber will be taken up to suit the HYRA-INGA combined facility. The target chamber and detector chamber design has started and are expected to be ready by end of January next year. Initial tests of this stage with gas-filled operation using radioactive source and beams from LINAC are planned for March 2006. The second stage magnets are in the design stage and expected to be ready for testing around March 2006. The corresponding power supplies are being developed indigenously. Electrostatic dipole and the superconducting quadrupole doublet Q1 and Q2 are expected to take longer time as they involve part indigenisation to reduce the cost.



**Magnets of first stage of HYRA aligned in Phase II experimental area at IUAC**

## Beam Transport Group

The prototype 100V, 300A power supply developed for HYRA project has been given final shape. The product is now ready for use. Specifications are :

| | |
|---|---|
| Output Current Rating | : 0-300A |
| Output Current Stability | : 10PPM (for 8hrs) |
| Output Voltage Rating | : 100V |

The prototype power supply developed for Magnetic scanner to be used in Material science line in BH-II is now in its final shape. Specifications are: 50 V, 50A Frequency-50Hz, wave shape-triangular.This is to be used for scanning in X-plane. A similar power supply 5V, 70A is being developed for scanning in Y-plane.

A low cost magnetic spectrometer to analyse electrons of different energy; an equipment for M.Sc physics experiment in University has been developed. Specifications are:

| | |
|---|---|
| Magnetic field strength(max.) | : 500Gauss |
| Maximum Beta energy | : 2.5MeV |
| Transmission | : $10^{-3}$ |
| Resolution | : 5% |

Similarly a spark counter for detecting alpha rays has been developed.

Any University willing to have similar equipments for its laboratory can contact Dr A.Mandal (mandal@nsc.res.in).

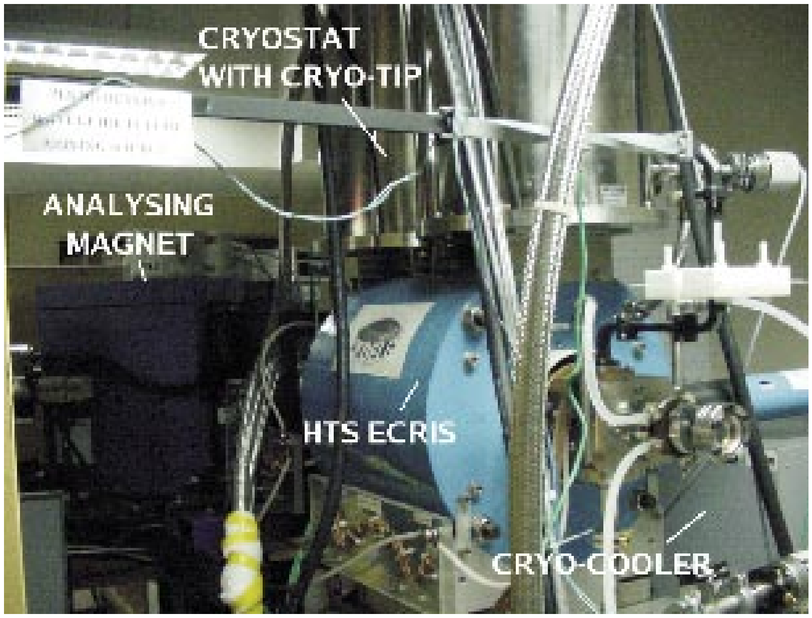


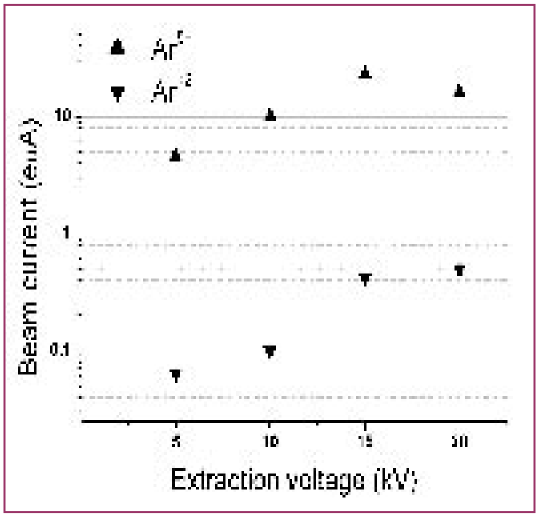

**Fig. 1. View of the installed HTS ECR ion source and analysing magnet**

## Performance of High Temperature Superconducting ECRIS

The First High Temperature Superconducting Electron Cyclotron Resonance Ion Source (HTS-ECRIS) called PKDELIS operational at both 14.5 and 18 GHz has been installed.

A view of the HTS (Bi-2223) ECR ion source and related components installed at ground potential is shown in figure 1. The HTS coils which are housed in separate cryostats are cooled to below 23 K for optimum operation and have been working satisfactorily. The source is powered by a 18 GHz, 1.7 kW klystron generator. The plasma chamber and the bias tube is water cooled using a dedicated, portable, closed cycle water cooling system. If the temperature or the water flow rate does not conform to within specified limits, the RF generator will be forced to shut down to protect the plasma chamber and the permanent magnets of the hexapole. A small, medium resolution, large acceptance, air-cooled, 90° analysing magnet has been installed and coupled close to the source. The aperture and radius of the magnet was chosen to be 80 mm and 300 mm respectively. A multi-electrode, air cooled extraction system has been coupled between the source and the analysing magnet with a pumping port installed just after the extraction system. It consists of three cylindrical electrodes, which can be biased properly to achieve reasonable transmission and mass resolution. A 1 kW, water-cooled Faraday cup is used for measuring the analysed beam currents. The x-ray radiation levels around the source were measured at different coil currents in the HTS coils and RF power levels. At relatively higher coil currents and RF power levels of the order of 500 W, the radiation levels were maximum on the extraction side and measured to be of the order of 7 rad/hour. In order to be in the safe working limit during regular operations, lead shielding structures around and close to the source were designed and positioned close to the source.

The current measurements were determined for $Ar^{8+}$ and $Ar^{12+}$ beams as a function of extraction voltage. Figure 2(a) shows the transmission of these beams measured at 10 Watts of RF power with coil currents set at 130 A and 120 A on the injection and extraction coils respectively. Figure 2(b) shows the charge state distributions typical for argon at two different coil current settings measured at lowest RF power level of 10 Watts and extraction voltage of 10 kV. At lowest power levels of 10 Watts and at a particular setting of the coil currents, the peak of the distribution shifts to 8+.



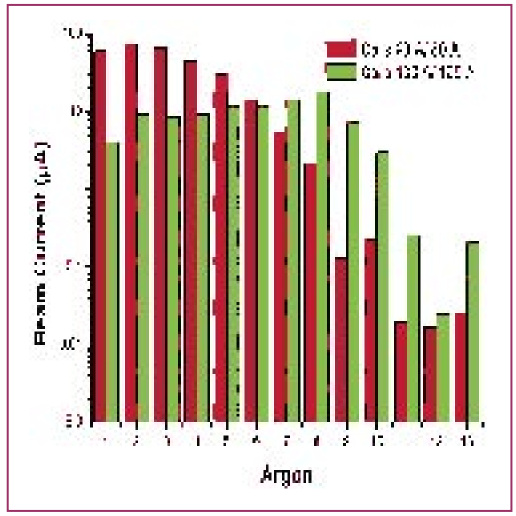




**Fig. 2 (a) Extracted currents**

**(b) Charge state distribution for argon**

## Improvement of Experimental facilities at Universities

IUAC is continuing the activities to improve the laboratory facilities at the Universities. A low cost "Radiation Detection and Analysis System" has been developed and given to nearly thirty physics departments at different Universities. Any university department or govt. aided college having an alpha source and wanting to introduce radiation detection experiments in the M.Sc. practicals may write to us if they are interested in this equipment. It is given free of cost after a three days training conducted periodically for the faculty members who will be using it.

In order to encourage computer assisted experiments and data analysis techniques we have designed a simple and cost effective PC interface named Phoenix. Several experiments like measurement of acceleration due to gravity, velocity of sound etc. have been designed using it. We have conducted ten "one day workshops" at different universities to demonstrate this unit and a training program also was conducted for a selected group of teachers from different universities at IUAC. The design and fabrication details are available on the web. Three commercial vendors are currently selling this unit for Rs.3500/-. For more details about Phoenix visit our site www.nsc.res.in.

## Accelerator Mass Spectrometry

The Accelerator Mass Spectrometry facility at IUAC is ready and open for the users to carry out $^{10}$Be measurement work. Over the years we have been working on the installation of new components to the facility. These are multi cathode ion source remotely controlled by software, recirculating turbos at the terminal for gas stripper, an offset Faraday cup after analyzer magnet, and dedicated AMS beam line. AMS beam line is equipped with Wien filter, a quadrupole doublet, a double slit, an AMS chamber followed by a gas cell and Multi-Anode Gas Ionization Chamber (MAGIC).

Initially, measurement was carried out with standard sample SRM 4325 procured from NIST, USA. First standard solution (in $BeCl_2$ form) was converted in BeO powder form using specific chemical procedure and then after mixing with Ag/Nb, it was used as a cathode in the ion source. Fig.1 shows the 2D spectrum obtained from MAGIC. The ratio of $^{10}$Be/$^{9}$Be came out in above measurement as $3.01\times10^{-11}$, and $3.47 \times 10^{-11}$ from two samples, which is within ~15% of known measured value for SRM 4325 ($3.06 \times 10^{-11}$).

In the next run we measured $^{10}Be/^{9}Be$ in the samples prepared with Mn nodules. These samples were collected and prepared by Jitendra Pattanaik and his group from Earth Science Dept. of Pondicherry Central University. Measurement was done using simultaneous injection technique. Fig. 2 shows the spectrum of $^{10}Be$ measurement from Mn nodule sample. The $^{10}Be/^{9}Be$ ratio came out in this measurement as $7 \times 10^{-11}$.

## AMS Workshop

A workshop was organized at IUAC on Accelerator Mass Spectroscopy, on Sep.23, 2005 for future planning and utilization of the AMS facility in research. About 50 participants attended the workshop from different universities and institutes including AMS group members of IUAC. During inaugural address Prof. V.S. Ramamurthi, Secretary, DST, appreciated AMS facility development and described the use of AMS in different fields of science. There were 10 talks including 3 talks representing all three Pelletron laboratories in India. Other talks were on the sample preparation and application areas of AMS. The workshop was quite informative and it came out as a good platform to built user base.

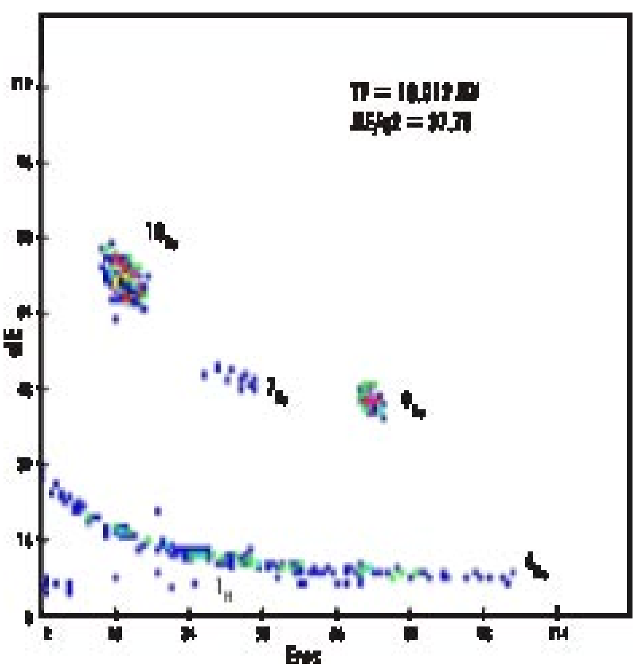


**Fig.1 Two dimensional spectrum of $^{10}Be$ measurement from standard sample SRM 4325**

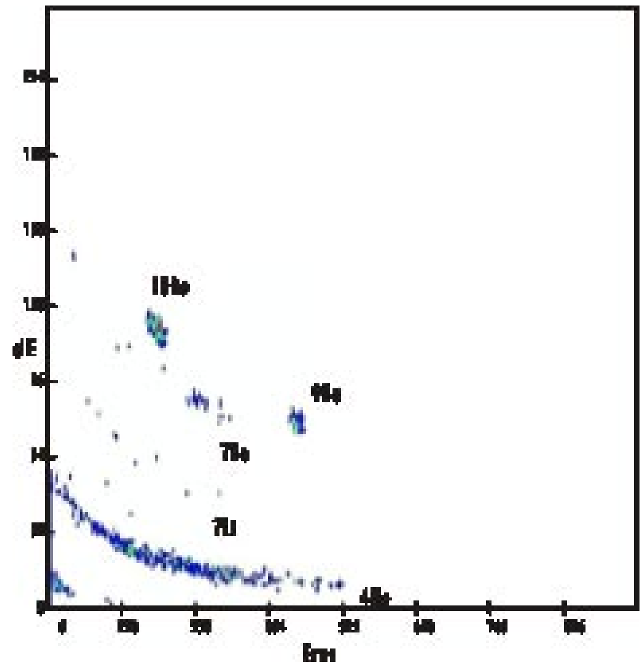


**Fig.2 Two dimensional spectrum of $^{10}Be$ measurement from sample prepared with Manganese modules**

## Materials Science Activities

An Indo German workshop workshop (a joint venture of Nuclear Science Centre New Delhi and University of Stuttgart) on 'Synthesis and modification of nano-structured materials by energetic ion beams' was organized at the auditorium of international centre of genetic engineering and biotechnology from 20th Feb. to 24th Feb. 2005. A two days school on 'Nanostructuring by ion beams' was organized preceding the workshop on 18 th and 19th Feb. 2005. Both the events were held under the chairmanship of Dr. Amit Roy, Director of Nuclear Science Centre (now renamed as Inter University Accelerator Centre, IUAC). The convener for the events were Dr. D.K. Avasthi, IUAC, New Delhi and Dr. W. Bolse, University of Stuttgart.The school covered the basic talks and tutorial lectures by experts in various areas. We owe special thanks to the school speakers, Prof. H.C. Verma (IIT Kanpur), Prof. Moser (SLS Singapore), Prof. L.Wang (Taiwan), Dr. M. Toulemonde (CIRIL Caen, France), Dr. J.C. Pivin (CSNSSM Orsay), Dr. I. Vickridge (Univers Paris Sud, France), Prof. B.R. Mehta (IIT New Delhi) and Mr. A. Tripathi (IUAC New Delhi).There were two dinner talks. One of them by Dr. P.I. John, Director, Institute of Plasms Research Ahemdabasd, on

'Plasma processing' on 19th before dinner. The other dinner talk was on 23rd evening by Prof. F. Faupel, Chairman of multicomponent materials, Technical Faculty, Kiel University.

The Indo German workshop covered a wide research area with focus on the following themes: buried nano-particles by ion implantation, Ion Track Technology, generation of nanostructures by SHI, stability of nanostructures against ion irradiation, nano particle synthesis by plasma assisted processes, related Topics: ion beam mixing, sputtering, ion beam induced phase transformations, Swift Heavy Ions in materials engineering and characterization.

There were one hundred and ninty five participants including twenty foreigners. Apart from eleven invited speakers from Germany, there were participants from France, Belgium, Poland, Singapore, Japan and Taiwan. Ten invited speakers were from the Indian universities and institutes. There were nineteen oral presentations and about one hundred ten posters. One hundred and eleven papers were submitted in the workshop for publication in the proceedings. These were refereed by seventy six referees, nominated in consultation with Dr. Christina Trautmann of GSI, joint editor of Nuclear Instruments and Methods. Out of one hundred and ten papers submitted by the participants, sixty eight papers were recommended for publication after refereeing.

An acquaintance program was organized in Gwalior university on 26th August. The activity was coordinated by Prof. Tiwari, Gwalior university and Dr. D.K. Avasthi of IUAC, New Delhi. There were about eighty participants from the university and colleges of Madhya Pradesh. This was inaugurated by the Vice Chancellor, Prof. Satyaprakash.

The ongoing DST project on Intensifying Research in High Priority Areas (IRHPA), has been implemented with regard to the setting up the following four facilities: (i) On-line ERDA in phase 2 beam line (ii) In-situ XRD in phase 2 beam line (iii) Quadrupole Mass Analyzer (QMA) in UHV chamber of phase 1 beam line and (iv) AFM/C-AFM/MFM/STM. An indigenously designed detector is fabricated and tested. It is installed in the phase 2 beam line. The test with ion beam will be taken up shortly. A vacuum chamber with Kapton windows for incident and diffracted X-rays has been mounted on the Goniometer and connected with the beam line. It has been tested for vacuum and is ready to take the beam for an in-situ experiment. QMA has been tested with ion source and experiment with ion beam will be performed to look in to the fragments of fullerene under swift heavy ion irradiation. AFM/MFM/C-AFM is routinely being used for studies of ion beam irradiated surfaces.

There have been recent interesting results on (i) tuning the temperature coefficient of resistance of LCMO thin films by ion beam parameters and (ii) the magnetism in irradiated fullerene thin film, revealed by magnetic force microscopy. The later is under detailed investigation.

## Indian National Gamma Array (INGA)

The Department of Science and Technology (DST) has released the first installment of sanctioned fund for Indian National Gamma Array (INGA) project. The purchase / fabrication initiatives are being taken for detectors, detector support structure with movement mechanism, processing electronics including cables, power supplies, data Acquisition system, beamline, vacuum equipments, and liquid nitrogen automatic filling system for clover detectors. The first beam test with INGA and LINAC beam in beam hall II is expected around middle of 2006.

## Status of 15 UD Pelletron (1st April to 31st October, 2005)

Pelletron has operated well during this period but a few problems have also been encountered during this duration and tank had to be opened to attend to these problems. There were three tank openings, two of which were unscheduled. The problems encountered during two unscheduled tank openings were related to charging system and the gas stripper controller.

The machine has been unit wise conditioned up to a maximum terminal voltage of 14.14 MV and as per request of users, beam was delivered at 13.3 MV. Out of total beam time of 2368 hours, 342 hours were used for pulsed beam runs using multi harmonic buncher. 16O beam was bunched for these experiments. All the pulsed beam runs were quite stable.

An ion source test bench, which was designed and fabricated for the developments of new beams, is near completion. Recently an electrostatic quadrupole and a steerer were designed, fabricated and installed in Ion source test bench. These optical elements have been incorporated for improvements in the ion beam optics of test bench.

The original foil stripper position readback arrangement had the problem of position readback. This system was modified by designing a three digit BCD counter and 8 bit DAC. Although this new readback system has worked better than original o ne but during tank sparks, it used to generate arbitrary position readback numbers. A new software counter has been developed and incorporated in the system. This position readback arrangement is working fine now.

A new interlock system has also been designed and incorporated for proton beam runs. In this new interlock system, the proton beam run is identified by magnetic field value of injector magnet and entire beam hall (all experimental areas) has to be interlocked before injecting the proton ion beam into the accelerator. This interlock helps to stop proton beam at a faraday cup in pre-acceleration area to prevent any acceleration of proton beam without interlocking.

## Statistical Summary

| | | |
|---|---|---|
| Total Chain Hours | = | 4224 Hrs. |
| User time | = | 2456 Hrs. |
| Beam change time | = | 5 Hrs. |
| Machine Breakdown time | = | 217 Hrs. |
| Machine maintenance | = | 888 Hrs. |
| Conditioning | = | 1546 Hrs. |

The uptime of machine for this period was 94.86%. The beam utilization time was 58.14%.

## User List

April – October, 2005

| University/ Institute / College | Shifts utilized |
|---|---|
| Allahabad University | 20 |
| AM University, Aligarh | 25 |
| Anna University, Chennai | 3 |
| Bangalore University | 15 |
| BH University, Varanasi | 3 |
| Calcutta University | 20 |
| Cochin University | 3 |
| Delhi University | 17 |
| GBPant University, Pantnagar | 3 |
| H P University, Simla | 2 |
| HNB Garhwal University | 3 |
| Hyderabad University | 4 |
| IIT, Delhi | 2 |
| IIT, Mumbai | 15 |
| IIT, Roorkee | 15 |
| IUAC ( Formerly NSC) | 29 |
| IUC, Indore | 4 |
| JMI University, Delhi | 2 |
| Kiel University, Germany | 1.5 |
| Kongunadu College, Kerala | 3 |
| Kurukshetra University | 6 |
| MD University, Rohtak | 1 |
| NCSR, France | 3 |
| Punjab University | 40 |
| Punjabi University, Patiala | 6 |
| Rajasthan University | 8 |
| RBS College, Agra | 3 |
| Saurashtra University | 5 |
| SINP, Kolkata | 18 |
| Tezpur University | 6 |