2. ACCELERATOR AUGMENTATION

2.1 HIGH CURRENT INJECTOR

The High Current Injector (HCI) Project will accelerate the ion beam from ECR source using normal temperature Radio-Frequency Quadrupole (RFQ), and IH type Drift Tube Linac (DTL) to match the input velocity at our existing superconducting linear accelerator. This year beam was successfully accelerated (A/Q=3 & 2) through RFQ and first DTL cavity to achieve the design energy output of 325 keV/amu.

2.1.1 18 GHz HTS ECR Ion Source, PKDELIS and LEBT

G. Rodrigues, P. S. Lakshmy, Y. Mathur, Sarvesh Kumar, U. K. Rao & A. Sarkar

(a) Ion Source Operation and Measured Radiation Levels

The low energy beam transport section (LEBT) after the HTS ECR ion source was modified due to huge beam loss caused by the large distance between ion source and the analyzer magnet. The ion Source was shifted towards the magnet by removing the existing Faraday cup and beam profile monitor. The water cooled extraction system was replaced with an air cooled extraction system. The small HV platform for housing the bias power supply was re-positioned and refurbished by placing it on a rail close to the ion source. The extracted beam intensities improved by a factor of 10 after the LEBT modification. Various gaseous beams like Ar, Ne, N_2, O_2, He etc. were developed. However, due to radiation shielding issues around the ion source, we could not run at relatively higher levels of RF power.

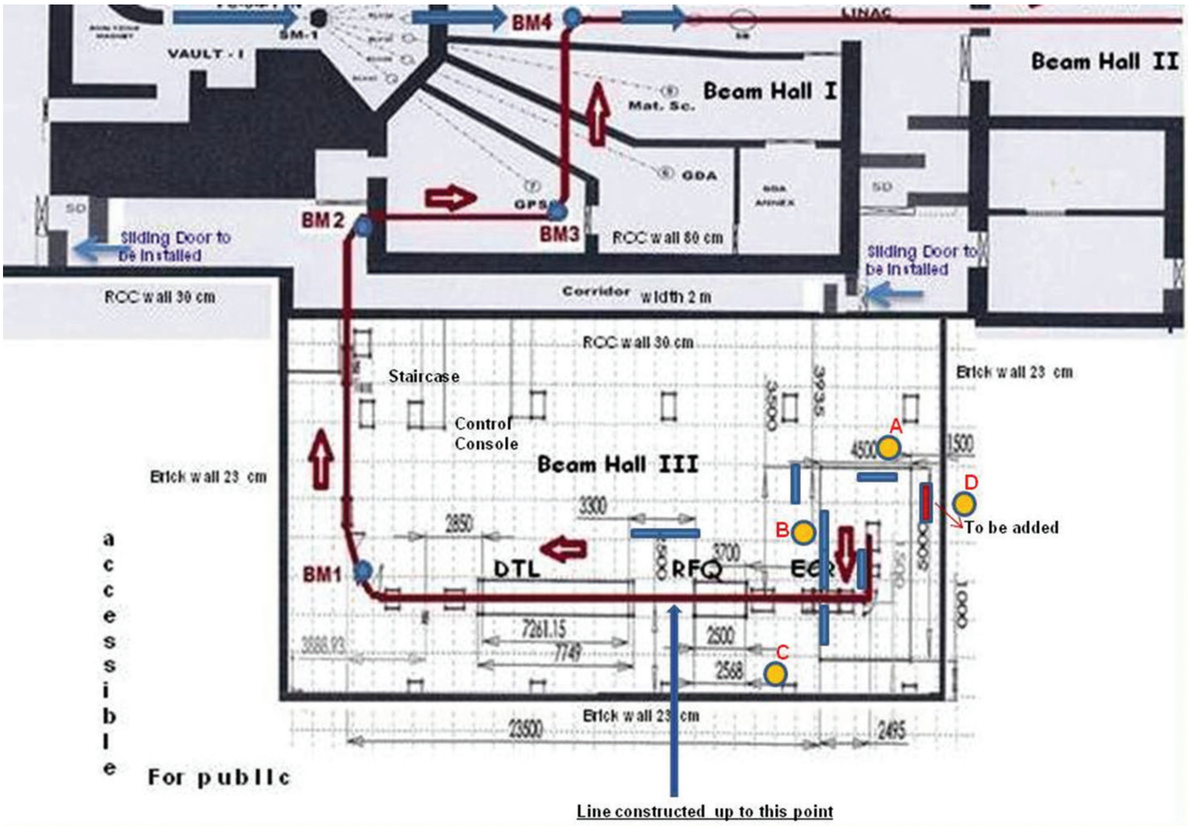


Fig.1. Radiation survey around beam hall III when the ion source was powered at various levels of RF power

Beam Hall III was surveyed thoroughly, with four RF power levels 100, 400,700 and 920 Watt (Fig.1). The whole area was thoroughly monitored. The staircase area (downstairs from the control/data room) and the control console area were completely safe from radiation point of view (<50 μR/hr, even with maximum power). The points A, B, C marked in the picture were the radiation-wise most hot points in the beam hall, but still they did not cross 350 μR/hr with maximum power (permissible for radiation workers is 1000 μR/hr). Point D behind the glass back door of the cage however showed non permissible radiation level, which can be brought down to safe level by using a movable lead shield covering the glass door. (While surveying this, movable lead shield was not in position, but will be put back in place). Hence, with all lead shields in proper position (as per figure 1.), the HCI Beam Hall is completely safe for a radiation worker outside the source cage. No extra shielding is found necessary. However, entry of non radiation workers should be restricted. The average radiation level even with maximum power is well below the permissible limit. But radiation workers should ensure using radiation badges as a compulsory measure.

(b) Failure of 18 GHz Klystron and Water Chiller

The RF generator for the ion source has been running over 16 years and its functioning and operation has been deteriorating. This has resulted in downtime of the ion source. We have had problems with the water chiller which is generally being used for cooling the cryo-coolers. This has also resulted in the downtime of the ion source. Efforts are underway to minimize these problems with both these systems.

(c) Beam Acceleration Tests

Ion source was in continuous operation for beam acceleration tests of HCI during last academic year. The energy measurement from RFQ and DTL#1 was carried out using a newly installed beam line consists of spiral buncher, DTL, quadrupoles, steerers, beam diagnostic elements etc. after RFQ, along with the 45^0 bending magnet (Figure 2.). Beam acceleration tests for DTL#1 was carried out using Ne^{8+} and N^{5+} DC beams. The boosted energy from RFQ and DTL#1 were 188 keV/amu and 137 keV/amu respectively. Spiral buncher was tested with Ne^{8+} (bunched beam). The bunch width at fast Faraday cup was measured to be 2.42 ns. The maximum DC beam transmission achieved upto fast Faraday cup was 75%. Efforts have been made to look into the reasons for DC as well as bunched beam transmission loss after RFQ and DTL#1 in a stepwise manner and different methods were tried to streamline the beam tuning process for optimum transmission.

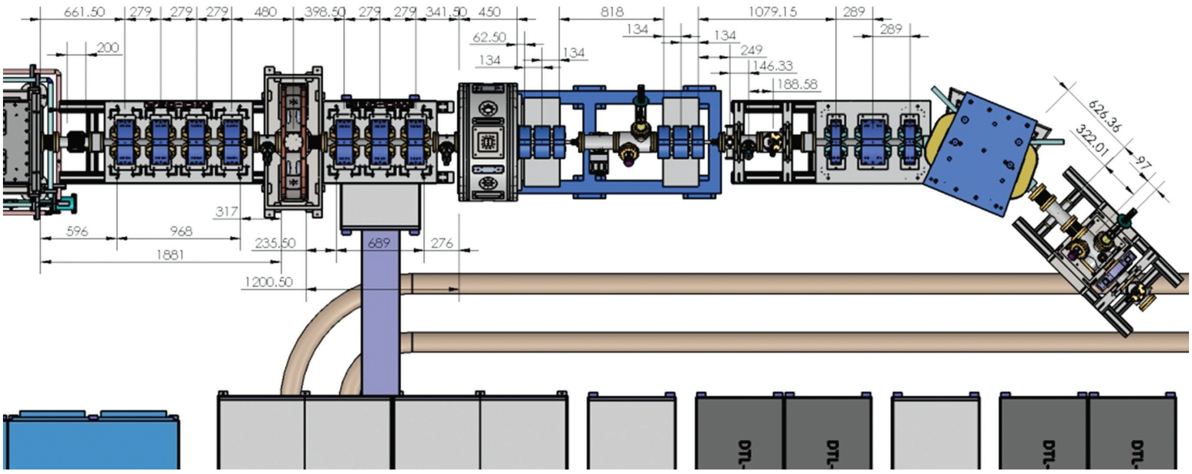


Fig.2. New test layout for DTL, spiral buncher and first cavity of DTL

(d) Multi-harmonic Buncher Test

Multi harmonic buncher tests were carried out to obtain optimum bunch width. The buncher tests were carried out with O^{6+} beam and the bunch width was measured using a fast Faraday cup. Ion source was optimized to have a stable beam. LEBT parameters and buncher parameters were optimized to obtain a stable bunch of 1.6 ns measured using a 4 GHz oscilloscope, which was desirable for maximum transmission through RFQ. A 3 mm collimator was installed close to the entrance of the buncher to minimize the rf defocusing. An improved collimation of the beam close to the entrance of the buncher as per the designed optics would improve the bunched width of the beam measured at the fast Faraday cup. Beam current of 2.8 μA was injected into the MHB. Stability of the beam bunch was also checked. Fig.3 shows the preamplifier signal from the fast Faraday cup using a 600MHz oscilloscope.

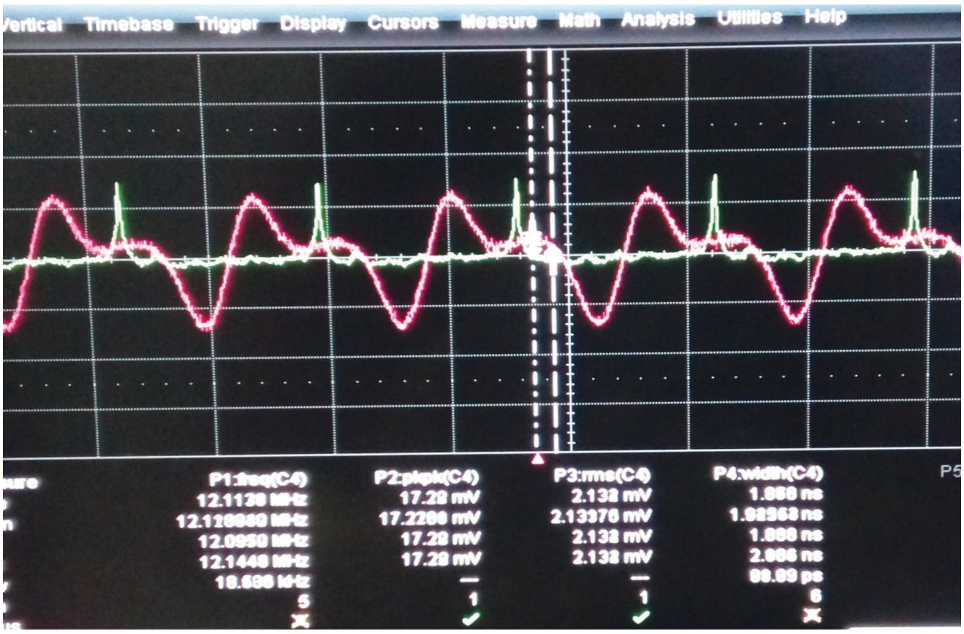


Fig.3 Bunch width measured using a 600MHz oscilloscope

2.1.2 Status of the Multi-Harmonic Buncher for the High Current Injector

A Sarkar, Sarvesh Kumar, Rajesh Kumar, R Ahuja, S K Suman, Y Mathur, P Barua, A Kothari, A J Malyadri, V V V Satyanarayana, B P Ajithkumar

A fully indigenously developed multi-harmonic buncher (MHB) was fabricated and commissioned in the beamline for the high current injector (HCI) at IUAC, New Delhi. The entire control electronics along with an RF power amplifier was integrated with the tank circuits connected to the bunching girds. Since beginning of 2017 it is operational and several beams from the ECR source have been bunched successfully using this system. Oxygen, Nitrogen, Helium and Neon beams have been bunched. The best FWHM observed was 2.5 ns as measured by the signal from a Fast Faraday Cup (FFC) on a 500 MHz oscilloscope. It was observed that an FWHM of 2.5 ns when measured on a 500 MHz oscilloscope measures 1.5ns on a 4 GHz oscilloscope. It was also observed that the beam convergence and divergence play a major role in the bunch width. Different A/q beams were bunched and it was observed that these scale linearly with the bunching voltage across the grids. Some of the results showing the bunched beam (FFC signals) and saw-tooth pick-up voltage (differentiated signal) as seen on the 500 MHz oscilloscope are shown in the following figures.

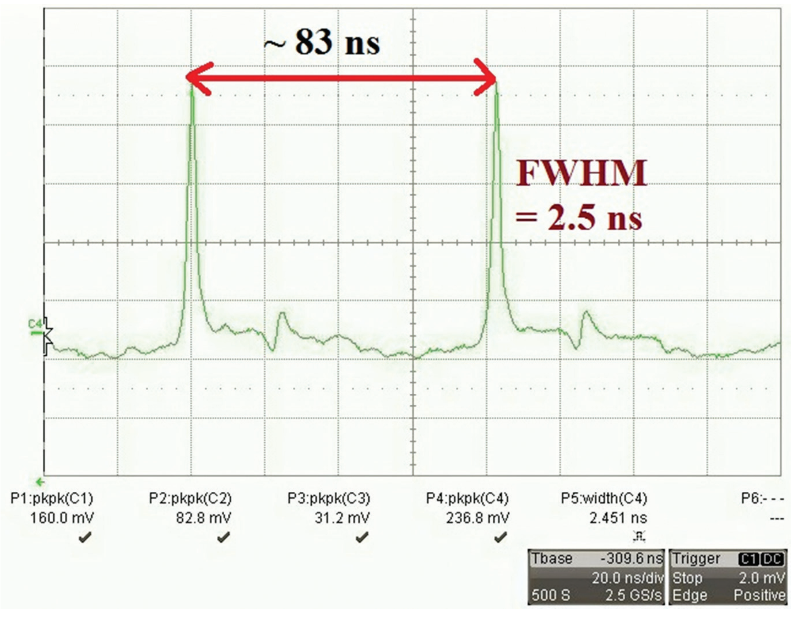


Fig.4 Bunch width measurment for O^{6+} ion beam

2.1.3 High Power RF Tests and Beam Test on Radio Frequency Quadrupole

Sugam Kumar, R. Ahuja, A. Kothari, C.P. Safvan

(a) Power Coupler and High Power Conditioning

To power the RFQ cavity we have designed a new prototype L-shaped water-cooled coupler. The newly designed RF coupler is based on a 6-1/8" coaxial waveguide, and its water-cooled inductive loop has to withstand up to 80kW power in CW operation at 48.5MHz. The coupling factor of the RF coupler insertion and rotation inside the coupling cell have been analyzed for different effective loop areas. The shape of the loop has been adopted in order to increase the coupling coefficient. The loop is made of two concentric copper pipes one of with diameter 12mm and other of 6mm. The loop has several bends which were introduced in order to optimize the coupling coefficient.

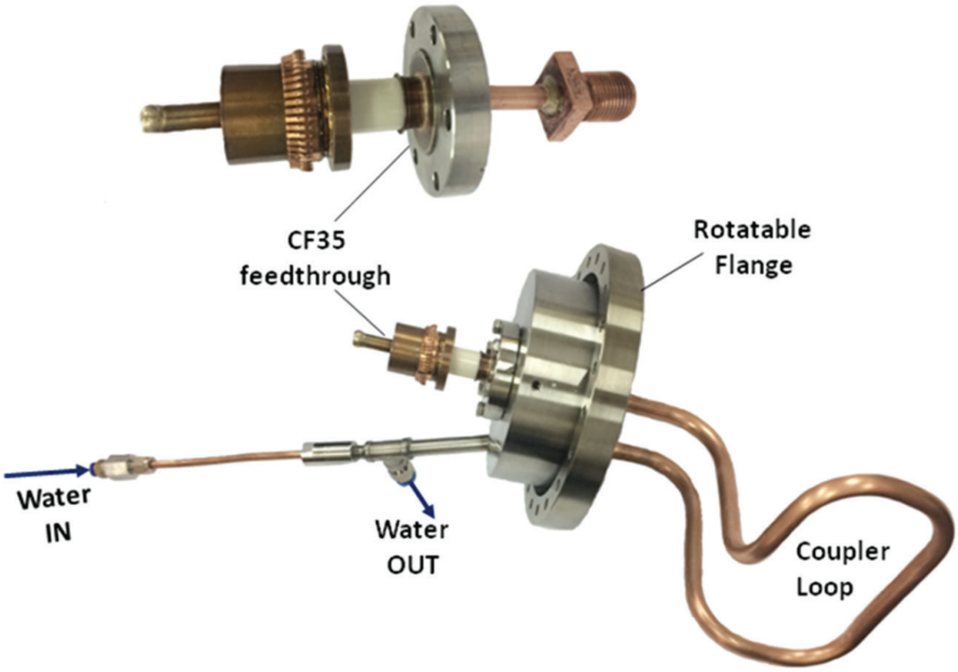


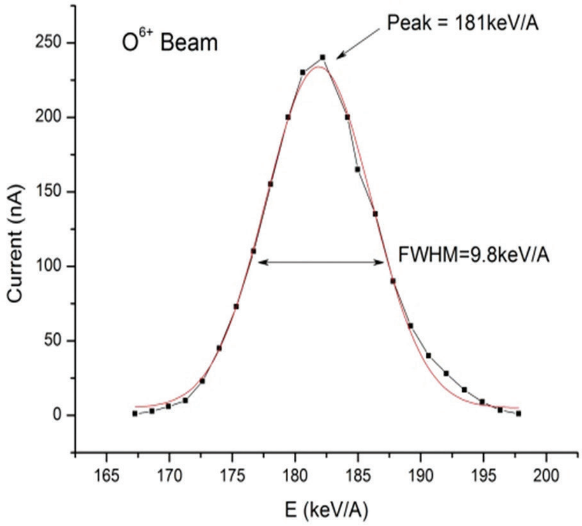
Figure 1: Assembled photo of the rotatable water-cooled L-shaped rf power coupler, a commercial alumina ceramic CF-35 feedthrough is used as a RF-window

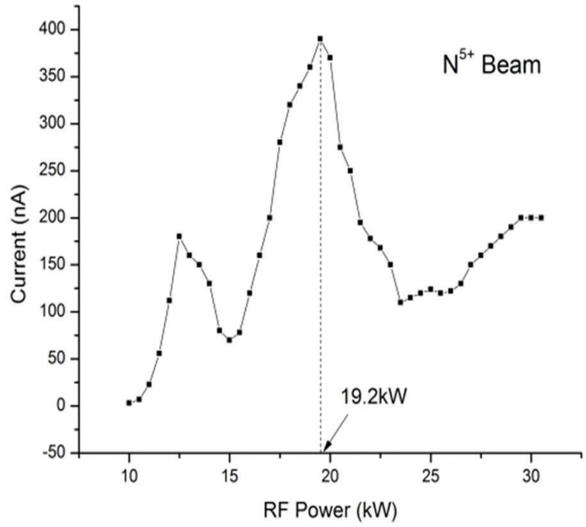
A commercially available Alumina ceramic based CF-35 feedthrough is used as an RF vacuum window. The feedthrough is screwed with stainless-steel custom-made CF 150 flange, which also has a water channel to cool the inductive loop. The central conductor of the 6-1/8" coaxial rigid line connected to the feedthrough with the help of Cu-Be finger strips. The outer conductor of the 6-1/8" coaxial line also connected to the CF 150 through Cu-Be finger strips. The one end of the inductive loop is then brazed to the central conductor of the feedthrough and another end is brazed on the rotatable CF150 flange of the coupling cell of the coupled RFQ cavity. Inside the loop and the feedthrough water flowing at maximum, 2 liters/min is used for the cooling of the loop surface as well as ceramic.

The purpose of high power rf tests were to check the rf and temperature stability of the RFQ also to survey both the RF and X-ray leaks from the RFQ cavity. The conditioning was started with an input power of 1 kW while carefully monitoring the cavity vacuum pressure and checking reflected power for signs of sparking. Slowly we reached to the 38kW forward power without any losing RF contacts. The RFQ was than conditioned at the 38kW power for few hours. We encounter a few major sparking or vacuum degradation in the cavity in the power range of 14-16kW, but above this power level cavity was performing reasonably well. After 6 hours of conditioning, the vacuum pressure in the cavity was 7.5×10^{-8} mbar at 38kW forward power. We observed marginal rise in the water temperature from 19^{0}C to 22^{0}C at the 38kW power.

(b) Beam Acceleration Test

The beam acceleration test setup was adopted and installed after the RFQ. The background pressure was maintained at around 5.65 x 10^{-7} mbar along the whole system. For the energy measurement of the accelerated beam, a 45^{0} bending magnet is installed after the RFQ. Two Faradays cups were installed just downstream the beam before the 45^0 bending magnet and another faraday cup system along with the BPM installed at the end of the diagnostic chamber to measure the current and the beam profile of the accelerated beam. The input current was measured with the fast faradays cup installed upstream the RFQ.





He^{2+}, 128keV of the O^{6+} and 112keV of the N^{5+} ion beam into the RFQ. The output beam energy is estimated from the momentum spectrum of the beam, which was taken with the 450-bending magnet. The input and output beam currents were measured with the faraday cups. The estimated output energy of He^{2+}, Ne^{8+}, O^{6+} and N^{5+} and other parameters are shown in the table 1.

Table 1: Accelerated parameters for He^{2+}, Ne^{8+}, O^{6+} and N^{5+} from 8keV/u to 180keV/u.

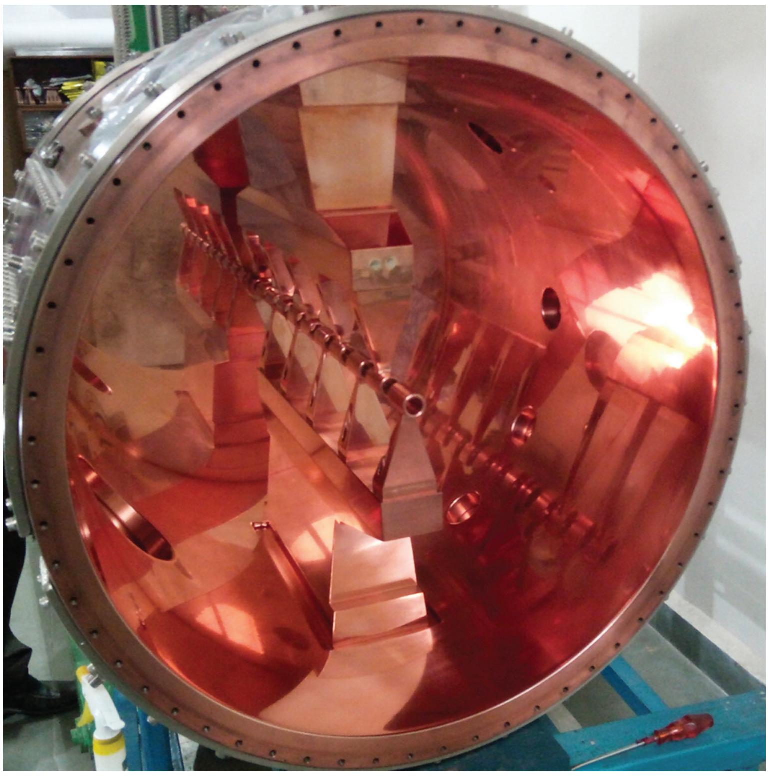
Beam	A/q	Ein(keV)	Eout(keV)	Cavity Pickup (mV)	Peak Power (kW)
He^{2+}	2.0	32	707 ± 3.0	38.2	13.2
Ne^{8+}	2.5	160	3640 ± 2.8	43.0	18.0
O^{6+}	2.67	128	2896 ± 2.7	43.5	18.3
N^{5+}	2.8	112	2520 ± 2.5	44.8	19.2

Successful acceleration of ion beams from 8keV/u to 180keV/u validates the design of RFQ modulation. It is just a matter of time and we should be able to accelerate the ions beam of A/q = 6 also from 8keV/u to 180keV/u. We are planning to accelerate bunched beam through the RFQ.

2.1.4 DRIFT TUBE LINAC RESONATOR

The role of the room temperature DTL in HCI is to accelerate the 180keV/u beam from the RFQ to 1.8 MeV/u. The DTL consists of 6 multiple gap IH type cavity resonators, operating at 97 MHz. The transverse focusing is done by compact quadrupole triplets, placed in between the resonator tanks. The design of the DTL incorporates bunching sections inside the cavity to take care of the longitudinal focusing. All the resonators are different with length ranging from 38 cm to 94 cm and power ranging from 5kW to 25kW.

Out of the six resonators, the first one has been installed and tested with beam. The energy gain has been verified. The second resonator assembly has been completed and powered up to 6kW. Resonator #3 and #6 are kept ready for power test. The power coupler and slow tuner assembly for the five resonators are progressing. All the components have been fabricated. The cavities will be power conditioned and assembled soon. An inside view of resonator #6 is shown below.



2.1.5 Travelling Wave Chopper

S Kedia, Rajesh Kumar and R Mehta

Chopping and Deflecting System (CDS) has been proposed to provide the chopped beam with various repetitions rates to the IUAC experimental facilities. The CDS has been designed, fabricated, assembled and tested with DC electronics.

The CDS has been installed in the Low Energy Ion Beam Facility (LEIBF). The test setup in LEIBF was configured to simulate actual layout of LEBT section (figure 1). Since the energy in the LEBT section is 8 keV/amu we have selected ion beam of Oxygen, Nitrogen, and Argon with various charge state to have energy of 8 keV/amu. A DC power supply has been developed indigenously and connected to the deflecting plates of the CDS. The DC power supply is capable of providing the voltage of 0 V to 1000 V. The CDS was tested with. The amount of deflection, at a distance of 750 mm, was measured for the various beams and different values of A/q. The measured and analytically calculated voltage matches closely, as presented in the table.

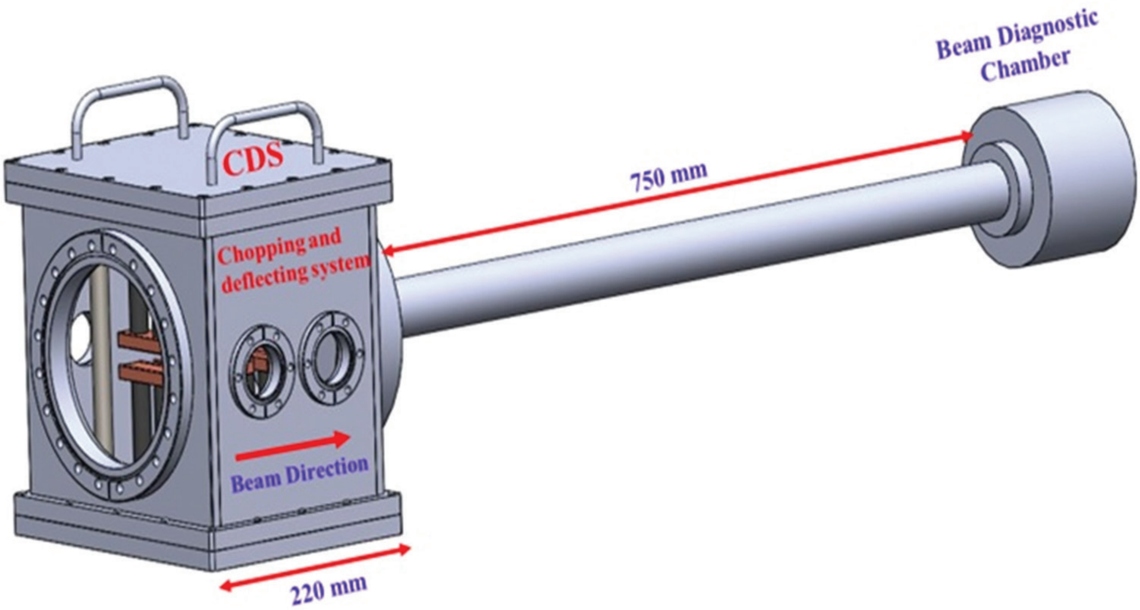


Figure 1. Schematic setup of CDS setup installed in the Low Energy Ion Beam Facility.

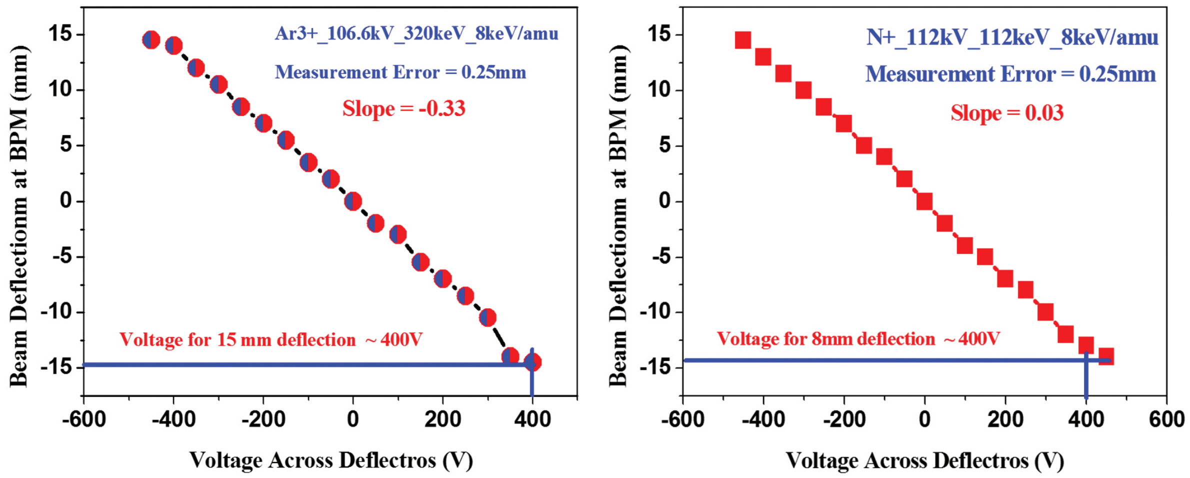


Figure 1. Schematic setup of CDS setup installed in the Low Energy Ion Beam Facility.

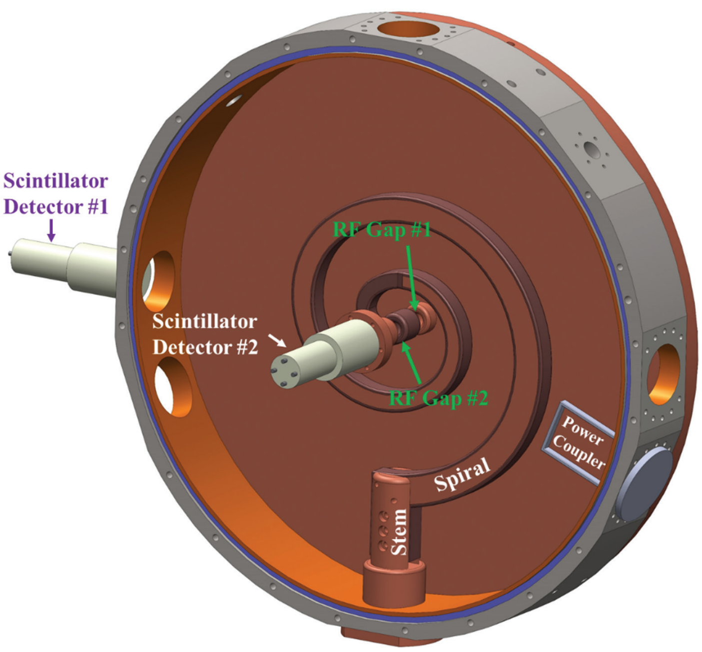
Voltage required for 15 mm deflection at 750 mm from CDS		
Theoretically Calculated Voltage	**CST Simulations**	**Experimentally Measured Voltage**
~350 V	330 V	~400 V

The experimentally measured voltage to deflect undesired charged particles match closely with the analytical value and CST simulated value. The measurement error is ~ ±0.5 mm because of instability and fluctuation in deck power supply.

2.1.6 HIGH POWER TEST OF 48.5 MHz SPIRAL BUNCHER FOR MEBT SECTION OF HCI

R Mehta, S Kedia, R V Hariwal, R Ahuja

A 48.5 MHz spiral buncher has been installed in the MEBT section of HCI beamline to provide the longitudinal beam matching at the entrance of the Drift Tube Linac (DTL) after successfully validating the design. The cylindrical chamber was fabricated of copper plated stainless-steel, while OFHC copper was used for the inner components. The measured quality factor, shunt impedance, resonance frequency, electric field profile and power requirement matches very well with simulated value. The bead-pull technique has been used to validate the electric field profile and to determine the various low-level RF parameters. A fine tuner has been developed and employed to correct the frequency shift during the high-power operations in the phase and amplitude lock condition. The cavity has been tested up to the full power of 1 kW to produce 27 kV across each gap.



The X-ray energy spectroscopy method was used to measure the gap voltage experimentally. The data analysis was carried out to find out the end point of the Bremsstrahlung spectrums. The endpoint of the Bremsstrahlung spectrum provides the information of maximum gap voltage across the drift tube. The various X-ray spectrums were fitted using a standard Bremsstrahlung equation at different power level. The error between analytically calculated and experimentally measured gap voltage is ~5%. The cavity has been successfully tested with the beam. The bunched beam was accelerated through DTL #1 to get designed energy gain of 325 kev/amu, with spiral buncher (SB) off. After optimizing the beam transmission through DTL #1 the SB was powered and tuned. The measured current was increased by factor of two indicating bunching effect. The cause of low transmission through DTL #1 was large bunched width at the entrance of the SB, ~7 ns. Since the acceptance of the SB is 2-3 ns, SB cannot provide efficient longitudinal matching at the DTL #1 entrance. The bunch length could not measure after spiral buncher since there is no longitudinal diagnostic device is available, in the MEBT section of HCI.

2.1.7 DEVELOPMENT OF COMPACT BEAM DIAGNOSTIC SYSTEM FOR HCI

R. V. Hariwal

(a) Development and Test of Compact Beam Diagnostic System (CBDS) for DTL-1 in HCI

Indigenously designed and developed Compact Beam Diagnostic System (CBDS) have been installed after the 450 bending magnet downstream to RFQ in the High Current Injector (HCI) at Inter-University Accelerator Centre (IUAC). The ultimate vacuum near the CBDS was observed to be ~1x10^{-7} mbar which shows that the separate pumping may not be required in the diagnostic box. The design validation of various diagnostic elements namely Faraday Cup, Slit scanner and electronic modules have been carried out by performing online test with 100 keV O^{6+} beam in the HCI beam line. Various operational aspects of a Python programmable logic controller (PLC) based electronic module and Graphical User Interface (GUI) have also been validated during this test. The installed CBDS-1 in HCI is shown in Fig.1.

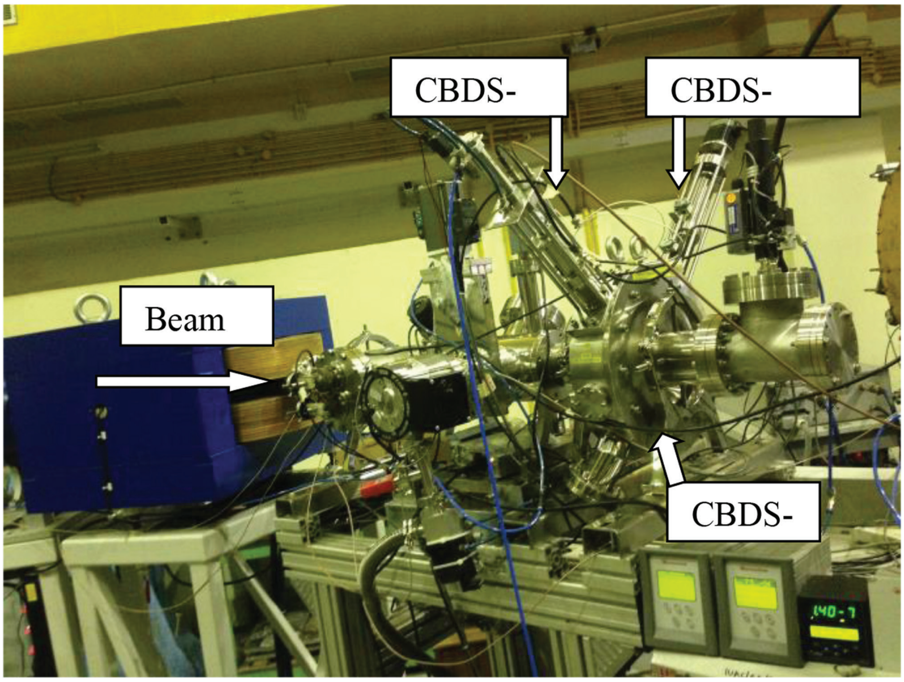


Fig.2.1.16: Modified 3D design of FC, SSC, CDB, CBDS and CBDS with DTL

Current measurements were performed in CBDS FC and NEC, USA made FC simultaneously to compare the magnitude of currents. It was observed that the currents measured in the CBDS FC are perfectly matching with the current measured in NEC FC. The beam current results are presented in Table 1.

Sr. No.	Beam 100 keV	Current in NEC FC	Current in CBDS FC	Results
1	16 O6+	154 nA	154 nA	Match
2	16 O6+	100 nA	100 nA	Match
3	16 O6+	70 nA	70 nA	Match
4	16 O6+	160 nA	160 nA	Match

The beam profiles in various tuning conditions are also checked and compared in the CBDS BPM (slit scanner) and NEC BPM (wire scanner). The result is discussed and shown in the Fig. 2.

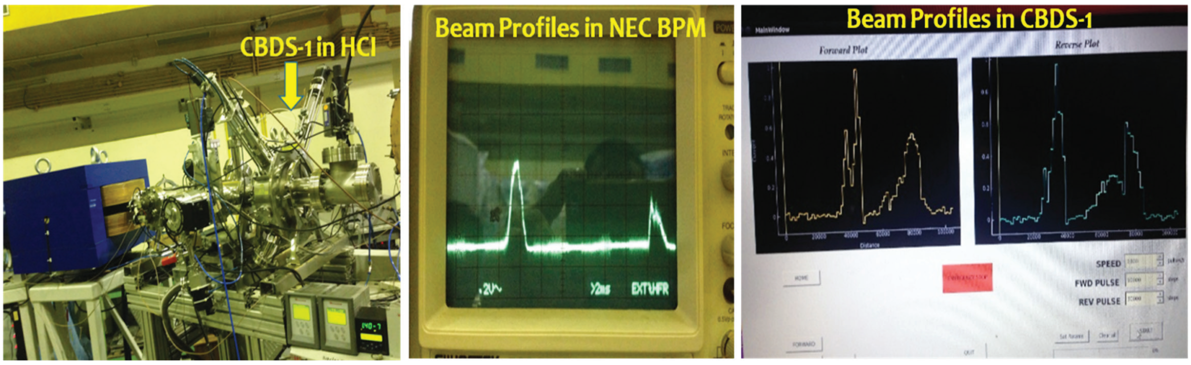


Fig. 2: Comparison of Beam profile in NEC BPM and CBDS BPM

Various currents and beam profiles have been checked in the CBDS-1 and it was found that the currents and profiles are perfectly matching with the currents and profiles measured in the standard NEC FC and BPM. The GUI and electronic module (PLC based stepper motor) for data acquisition has also been verified. These results validated the design, mechanical fabrication, electrical design and operation of various components of CBDS.

(b) Development of CBDS for DTL-2 to DTL-6 Cavities in HCI

The successful results of these tests lead to further develop the excellence, state-of-art design, robust and quality product of CBDS for DTL-2 to DTL-6 cavities in HCI. The present design needs further modifications to make it more professional and fail-safe from the operational aspects. The design modifications of the diagnostic box (DB), Faraday cup (FC) and Beam Profile Monitor (BPM) have been performed to fit them with DTL-2 cavities onwards. The 3D design and various assemblies have been made in the 3D-solid works. A prototype of newly designed elements like DB, FC and BPM are fabricated at IUAC. The PCD reduction from 300 mm (in DTL-1) to 180 mm of the DTL-2 entrance flange, made the design really critical and even more compact. Some important modification like electrical connections and water cooling techniques have also been carried out in this CBDS. This time, it was decided to use the Aluminum materials for the fabrication of DBs instead of stainless steel which reduces its weight significantly. One set of CBDS consisting of one diagnostic box, one FC and one BPM assembly are made successfully as per the modified design. This system is now compatible to DTL-2 to DTL-6 cavities in HCI. After the successful development of CBDS for DTL-2 cavity, it has been decided further to develop six more diagnostic boxes for HCI. The processes of six numbers of CBDS fabrications having uniform design for DTL-2 to DTL-6 are started. The procurement of the items to fabricate the eight numbers of FC, eight numbers of BPM and six numbers of DBs have also been initiated.

2.2 A COMPACT FREE ELECTRON LASER FACILITY TO PRODUCE INTENSE THz RADIATION

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[2]High Energy Accelerator Research Organization, KEK, Tsukuba, Japan
[3]Variable Energy Cyclotron Center, Kolkata, India
[4]Brookhaven National Laboratory,USA
[5]Deutsches Elektronen-Synchrotron, Germany

2.2.1 INTRODUCTION

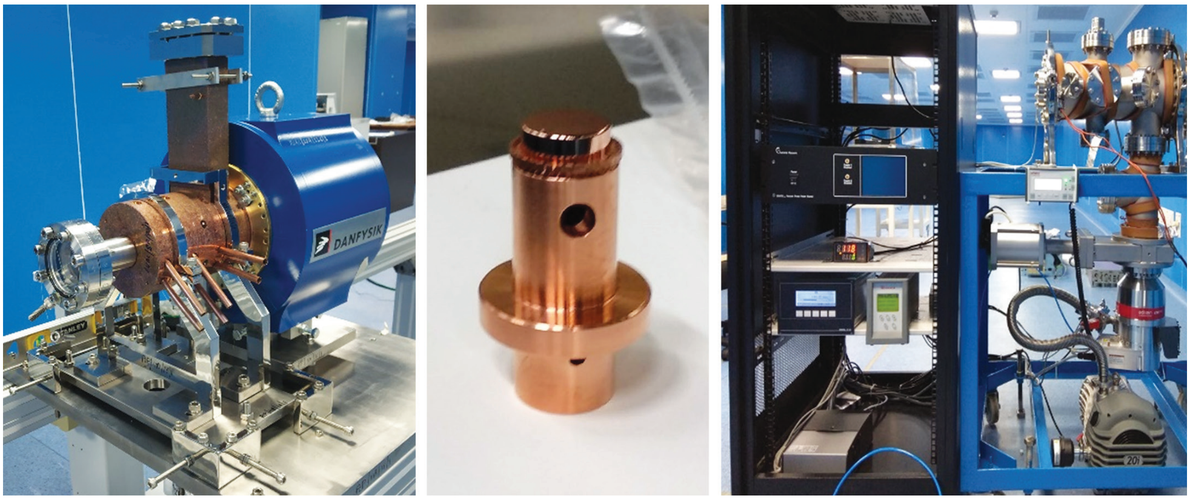
A compact pre-bunched Free Electron Laser facility named as Delhi Light Source (DLS) is under construction at IUAC since last five years [1]. A low emittance electron beam will be produced by a photocathode based normal conducting RF gun. The electron beam will be injected into a compact undulator magnet to produce intense THz radiation in the frequency range 0.18 – 3 THz. It is planned to produce electron beam initially from copper photocathode and subsequently from the semiconductor photocathode whose deposition system is in the final stage of fabrication. The commissioning of the FEL beam line has been started. The developmental status of the major subsystem is described below.

2.2.2 DEVELOPMENT OF VARIOUS SUBSYSTEMS OF PHASE-I OF DLS

The developments in the major areas of the Phase - I are listed in the following sections:

2.2.2.1 The Copper Cavity as the Electron Gun

The copper cavity along with the copper photocathode was fabricated and tested in the past and kept under vacuum at IUAC. Now the cavity and the solenoid have been installed and aligned in the beamline [figure 1(a)]. The copper photocathode along with the RF spring contact and the insertion chamber to insert the copper photocathode into the RF cavity are shown in figure 1(b) and 1 (c) respectively.



(a) (b) (c)

Figure 1. (a) Copper cavity as electron gun is installed with the solenoid magnet, (b) the copper photocathode plug with the RF contact spring, (c) the insertion chamber to insert the photocathode plug in to the electron gun.

2.2.2.2 The High Power RF System (Klystron, Modulator, Waveguide, Circulator, etc.)

The High Power RF system consists of Klystron, Modulator, vacuum based waveguide and vacuum Circulator, etc. The purchase order for the complete device was placed to Scandinova and the Factory Acceptance Test (FAT) has been conducted successfully at the site of the company. The required specifications mentioned in the tender documents have been achieved during the factory acceptance test. Now the device has arrived at IUAC and is waiting to be installed in its designated area of FEL. The schematic of the device and the arrangement during FAT are shown in figure 2.

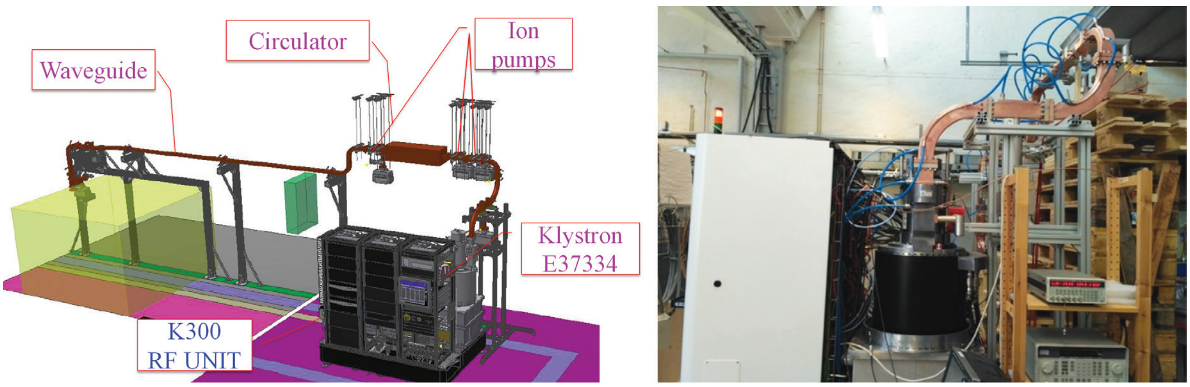


Figure 2. The schematic of the RF device and its arrangement during FAT at Scandinova, Sweeden.

2.2.2.3 Laser System to Produce Electron Beam from Photocathode

The main laser system for the free electron facility will be an Yb doped fiber laser system to produce multi micro bunch electron pulses from photocathode. Current design has been shown in the figure 3.

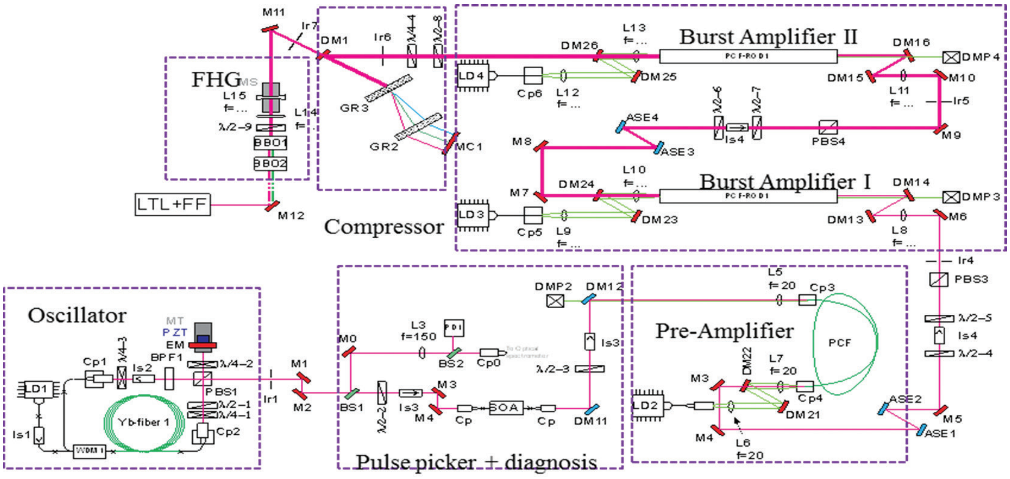
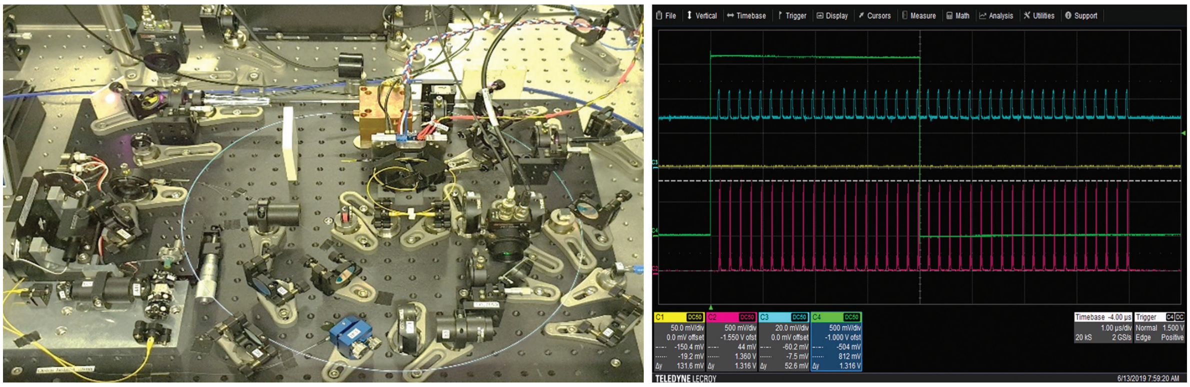


Figure 3. Fiber laser system latest design



(a) (b)

Figure 4. Oscillator+Pulse picker+preamplifer and its output with pulse seeding

As per the plan the total system is being assembled at KEK and later it will be shifted to IUAC. The main oscillator frequency will be 130 MHz which is the integer division of the main master clock (1300 MHz). The main oscillator is an Yb doped fiber to produce 1030 nm as fundamental which will be synchronized with the master clock that will drive the electron gun and klystron. The oscillator output is passed through a SOA based pulse picker to pick up the pulses at 5 MHz rep rate inside ~4 microsecond RF window with 3.125/6.25/12.5 Hz machine rate. So it will be a multibunch structure at 3.125/6.25/12.5 Hz rep rate with 200 ns separation between two bunches and then it is amplified by passing through a PCF fiber. The following is the oscillator+pulse picker+ pre amplifier system [Figure 4(a)] and its output [Figure 4(b)] assembled at KEK.

After this, two burst amplifiers (PCF ROD) are being added to increase the pulse energy. The splitting mechanism will split each laser into 1-16 pulses. The actual position of the splitting mechanism is still under consideration. It can be placed before or after amplification. Then finally after fourth harmonic conversion, the UV laser will be delivered to the photocathode using telescope system to produce multi-microbunch electron pulses. With 0.1 uJ/pulse we can produce maximum of 200 pC charge from Cs2Te photocathode. The average current can go upto ~24nA for 6pC charge/mircobunch for 20×16 multi-microbunch structure with 12.5 Hz rep rate.

2.2.2.4 Undulator

The design of the compact hybrid undulator magnet has been finalised with the code RADIA [2] to produce the radiation between 0.18 to 3.0 THz. When the procurement process for the undulator was started, IUAC was offered a spare Undulator for use by BESSY, Germany. Fortunately the parameters of BESSY's undulator was found to be very close to the designed parameters of IUAC's undulator and the comparison table is shown in Table-2. The beam optics and radiation simulation calculation [3] are performed again for the spare undulator of BESSY and the results are found to be same for both the designed one as well as BESSY's undulators.

Table: 1. Parameter Comparison of the Undulator

	Undulator designed for FEL project of IUAC	BESSY's Undulator to be used at IUAC's FEL
TechnologyHybrid planar	Planar	
Period length 50 mm	48mm	
Device length ~1.5 m	~ 1.7 m	
No of Periods28 (Full)	34 (Full)	
Magnetic gap 20 - 45 (mm)	17-42 (mm)	
Magnetic field0.62 - 0.11 (T)	0.62 - 0.11 (T)	
Undulator parameter (K)	2.89 - 0.61	2.73 -0.52
Wavelength0.18 - 3.0 (THz)	0.18 - 3.0 (THz)	
Beam Line Height	1.1m	1.5m

To validate the performance of BESSY's undulator (to be donated to IUAC), a detailed measurement of magnetic fields and remnant activation level was performed at BESSY. The magnetic measurement was found to be alright which validated the usability of the undulator at the FEL project of IUAC. After incorporating a few modifications and refurbishments, the undulator will be shipped to IUAC by the end of 2019 and is expected to be installed in the beam line in the beginning of 2020.

2.2.2.5 Beamline Commissioning

The commissioning of the beam line is presently going on. The RF cavity to be used as the electron gun has been installed and aligned along with the solenoid magnet. The insertion chamber along with the copper photocathode plug is waiting to be connected at the back side of the RF cavity. The high power RF device along with the waveguide are about to be commissioned and then the RF conditioning of the cavity will be started. The other components of the beam line are either procured or under the process of procurement. The various holding and alignment fixtures are designed and getting fabricated. The electromagnets e.g. quadrupoles, dipoles and steering magnets are already designed and being procured. The power supplies of all the electromagnets will be developed at IUAC.

2.2.3 Conclusion

The compact Free Electron Laser facility of IUAC is at the beginning stage of commissioning at IUAC. The important components of the facility e.g. the RF cavity, Copper photocathode, High Power RF device, the fibre laser system, solenoid magnet, etc. are either installed and will be installed in next few months. The Undulator to produce THz radiation will be installed at the beam line by the beginning of next year. It is expected that the electron beam and the THz radiation will be demonstrated by 2019 and 2020 respectively.

Reference

[1] S.Ghosh et al. Nuclear Instruments and Methods in Physics Research – B 402, (2017), page 358-363.
[2] RADIA, Online. Available: http://www.esrf.eu/ Accelerators/groups/Insertion Devices/Software/Radia.
[3] V.Joshi, et al., Nuclear Instruments and Methods in Physics Research – A 913, (2019), page 28-39.

2.3 2.45 GHz MICROWAVE ION SOURCE BASED FACILITY

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2.3.1 X-RAYS MEASUREMENTS

A 2.45 GHz microwave ion source based high flux system has been operational since the year 2017. The facility is frequently used for carrying out experiments in the fields of Materials Science and Plasma Physics. In the academic year 2018-19, plasma characterization with the help of X-ray measurements using NaI(Tl) detector was again carried out for oxygen plasma. The results have shown that X-rays in the energy range of 10 keV to 50 keV are being produced using RF power up to 100 W. This energy signature directly relates to the electron energy distribution function (EEDF) inside the plasma and are unusually high in this kind of ion sources.

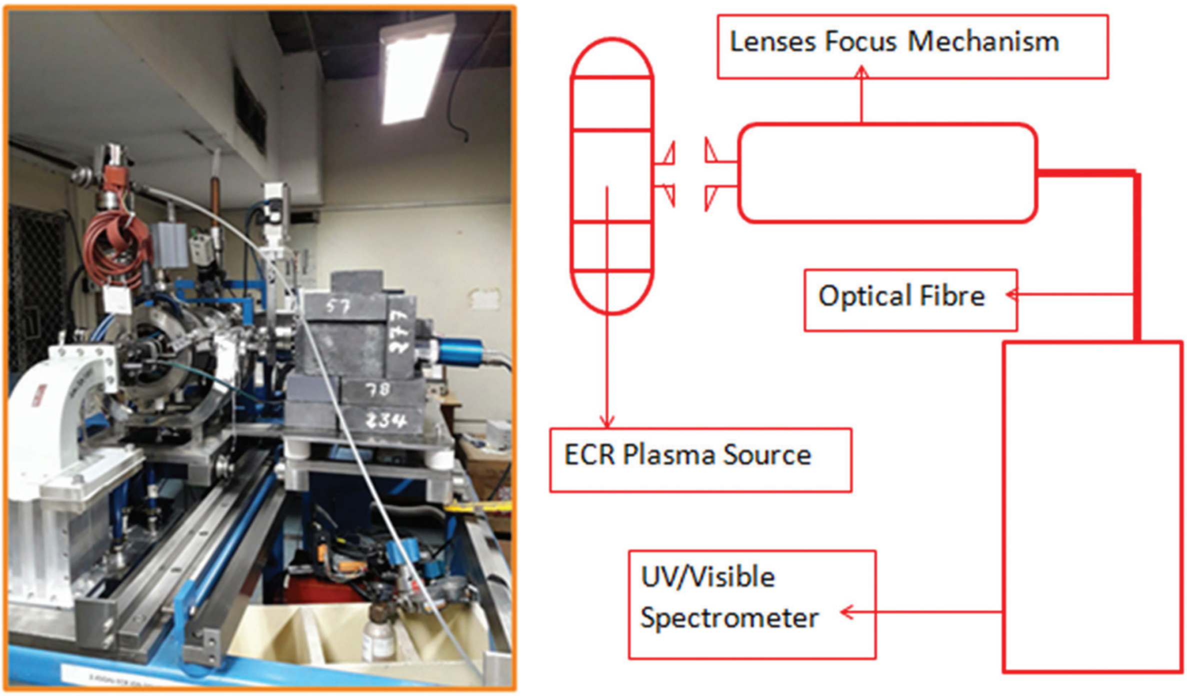
PIC simulations are undergoing investigations to study the effect of ambipolar and non-ambiploar diffusion mechanisms by looking into the effects of insulators placed inside the plasma chamber. These information can be useful to extract intense ion beams. The aim is to compare the simulations with recent experimental observations in plasmas exhibiting ambipolar and non-ambipolar diffusion mechanisms.

2.3.2 ATOMIC SPECTROSCOPY USING ECR PLASMA

Spectroscopy is a standard diagnostic technique for astrophysical and laboratory plasmas, the electron cyclotron resonance (ECR) ion sources are excellent tool to carry out such diagnostics. These studies include calibration of density diagnostics, x-ray production by charge exchange, line identifications and accurate wavelength measurements, and benchmark data for ionization balance calculations. In the present work context, our main focus will be on measurements of relative line intensities in the vacuum ultraviolet spectral range (VUV) to visible range, and if possible some other important line spectra in X-ray region.

In VUV to visible region we can investigate the relative line intensities of the 2s2p ^3P-2p^2 ^3P and 2s^2 ^1S-2s2p ^2P transitions for C III, O V, Ne VII and other partially ionised atoms as a function of different ion source parameters [1]. For complete Collision – Radiative modelling of fusion devices the diagnostic lines from impurities like H_2, D_2, O_2, N_2, Ar and He is very indispensable to identify. For instance the ratio of 728.13 nm He-line to 750.39 nm Ar-line is used to determine electron temperature and ratio of 587.76 nm He-line to 706.52 nm Ar-line is sensitive to electron density [2]. In X-ray region closed shell, such helium-like or neon-like ions, which radiates predominantly in the X-ray range. This radiation can be used to diagnose the plasma conditions, such as the electron temperature, electron density, ion temperature, ion transport and diffusion, and bulk plasma motion. The radiation from highly charged ions contributes to the overall power loss of the plasma, and the associated radiative power loss can be severe and prevent ignition and burn, if the plasma contains too many heavy ions [3].

Ar ions, which happen to be the most abundant impurities in fusion plasma device, can serve as a great candidate for plasma parameter diagnosis in colder region. Apart from magnetic fusion plasma, the spectral lines of Ar I, Ar II and Ar III ions are indispensably required for ongoing development of plasma thrusters' diagnostics where Ar gas is used as propellant [4,5].



2.45 GHz ECR Ion source lab — Planned experimental Setup

Fig 1: Experimental Setup

All the above studies of magnetic fusion plasmas and plasma thrusters also consume a large amount of atomic data, especially in order to develop new spectral diagnostics. So along with experimental line identification work as mentioned above we will be working on the computation of reliable atomic data by the most advance and ab-initio calculations based on Multiconfiguration Dirac-Fock (MCDF) calculations [6]. These calculations will include the relativistic calculations of accurate energy levels, transition probabilities, wavelengths and oscillator strengths of the ions under study.

References:

[1] W. Pöffel et.al. Review of Scientific Instruments 61, 613 (1990); doi: 10.1063/1.1141934
[2] W.B. Wu et.al. AIP Conference Proceedings 2011, 020004 (2018); doi: 10.1063/1.5053246
[3] P Beiersdorfer, J. Phys. B: At. Mol. Opt. Phys. 43 (2010) 144008; doi:10.1088/0953-4075/43/14/144008
[4] K. Katsonis, 32nd International Electric Propulsion Conference (IEPC-2011-169); Germany
[5] T. Nandi et. al. Journal of Quantitative Spectroscopy & Radiative Transfer 112 (2011) 2771–2778
[6] Gajendra Singh et.al. J. Phys. B: At. Mol. Opt. Phys 49 (2016) 205002; doi:10.1088/0953-4075/49/20/205002