Chapter 4

EXPERIMENTAL FACILITIES IN BEAM HALL

4.1 Scattering chamber and neutron array

Mohit Kumar, N. Saneesh, K. S. Golda, A. Jhingan and P. Sugathan

4.1.1 Maintenance and servicing activities of GPSC

(with support from the Vacuum Laboratory)

A new vacuum control unit has been fabricated for the General Purpose Scattering Chamber (GPSC) as the old one was more than three decades old. The new control has been relocated from the original position to closer to the chamber in order to accommodate the modified beam line shielding wall to isolate GPSC beam line from HCI facility. The vacuum condition of the chamber has been tested satisfactorily after the modifications.

The alignment of X and Y position axes of detectors is very crucial in most of the nuclear physics experiments, in particular for the angular distribution measurements. The alignment of entrance port of GPSC and target ladder has been carried out afresh during the mounting of the detectors for a transfer reaction experiment carried out by users from Thapar Institute of Engineering and Technology.

4.1.2 Maintenance and servicing activities of NAND

(with support from the Vacuum, Beam Transport and Electronics Laboratories)

The time-of-flight (ToF) circuit of the pulse shape discrimination (PSD) module used in the National Array of Neutron Detectors (NAND) was modified last year to improve the electronic time resolution. The implementation of the new circuitry has resulted in an increase of current drawn by the electronic unit by 0.5 A. In order to avoid the over loading of the NIM bin power supply, the number of PSD modules used per bin has been reduced to 5 from the previous value of 6. The re-arrangement of the modules and the re-routing of input and output signal cables of the PSD modules has been carried out. A source test was carried out to ensure the proper functioning of the modules in the modified configuration.

Routine servicing and maintenance of the multi-channel high voltage power supplies used for the PMT bias has been carried out. After cleaning and servicing, each power supply was tested with dummy load before connecting it to the PMT. During NAND experiments, few numbers of signals are to be transported to/from the control room for beam and RF pulse monitoring. The patch panel near the Linac cryostat was used for this purpose in the past. A dedicated patch panel has been installed near the NAND structure to transfer signals directly to the control room and data room. Further, dedicated CAMAC/VME modules have been installed for the controllers of the beam line beam diagnostics elements such as Faraday-Cup, BPM and Beam line Valve.

Servicing of vacuum system included replacement of the faulty controller of Turbo-molecular pump used in the diagnostic box before NAND target chamber and ensured proper vacuum on the beam line to transport beam to the NAND facility. In another incident, the magnetic manipulator used for linear and rotary motion of the target ladder inside the NAND chamber stopped working during a source test prior to the user experiment. After a detailed examination, it was realized that one of the power supplies used in the control unit of the manipulator has gone faulty. The replacing of the original power supply with the same model was difficult within a short period of time as the manipulator and its accessories were imported from MDC, USA. An equivalent power supply with similar specifications was arranged from the local manufacturer and replaced to use in existing controller.

4.1.3 Experiments using GPSC and NAND

The following experiments were carried out in GPSC and NAND facilities using Pelletron and LINAC beam during last year.

Table 4.1: Experiments carried out using GPSC and NAND facilities

Sl. no.	User and affiliation	Title of the experiment	Beam	No. of shifts
1	Ms. Beant Kaur Thapar Institute, Patiala	Heavy ion reactions around the coulomb barrier	^{19}F	15
2	Ms. Pavneet Kaur IIT Roorkee	Study of fission fragment mass distribution of lead-island isotopes in heavy-ion induced fusion-fission reactions	^{32}S	18
3	Mr. Lakhyajit Sarma Gauhati University	Studies on fusion inhibition by measurements of complete, incomplete fusion and fission fragment cross-sections	^{30}Si	15
4	Ms. Pavneet Kaur IIT Roorkee	Study of fission fragment mass distribution of lead-island isotopes in heavy-ion induced fusion-fission reactions	^{28}Si	18
5	Mr. Raghav Aggarwal Panjab University	Study of neutron multiplicity and mass distribution in Pb region with NAND facility	^{48}Ti	24
6	Mr. Ramakrishna Reddy Andhra University	Study of different modes of fission in the uranium compound nuclei	^{30}Si	18
7	Mr. Punit Dubey Banaras Hindu University	Study of entrance channel effect on shell closure in fission dynamics		
8	Ms. Neha Dhanda Panjab University	Probing the fusion-fission dynamics in ^{201}Bi	^{16}O	15
9	Ms. Swapna Balakrishnan Calicut University	Pre-equilibrium neutron emission at high excitation energies	^{12}C	15

4.1.4 Upcoming experimental facility for low-energy nuclear physics research

It is planned to develop a new experimental facility for nuclear physics in beam hall I making use of the low-energy ion beams from upcoming HCI accelerator facility. The HCI beam can be used for low-energy nuclear physics experiments which are relevant for nuclear astrophysics studies. With the designed energy gain of 1.8 MeV/ Nucleon, beams up to ^{20}Ne can be obtained from HCI above coulomb barrier for symmetric reactions. For example 36 MeV ^{20}Ne is just above the Coulomb barrier for ^{20}Ne+^{27}Al reaction. Many nuclear reactions in this mass and energy regions have importance in Nuclear astrophysics studies.

Energy and angular distribution of the reaction products and measurement of cross-sections of various reactions would throw light into the details of the reaction mechanisms for both direct and compound nuclear reactions in low energy region. The proposed facility would be a complementary one to the existing nuclear physics facilities at IUAC.

A small scattering chamber will be placed after the third achromat in the HCI beam line for the upcoming facility. Beam will be taken through the alignment port of the first bending magnet of the achromat. A chamber placed at a distance of 3 meters from the exit port (alignment port) of the magnet. The existing beam line shielding wall will be modified to accommodate the chamber with its accessories. The design of the of the chamber is being carried out presently.

4.2 Gamma detector arrays: GDA and INGA

Yashraj, Indu Bala, U. Ghosh, R. Kumar and R. P. Singh

4.2.1 Maintenance activities

Routine maintenance of INGA electronics, vacuum system, detectors and LN2 system was carried out.

4.2.2 List of experiments performed in INGA / GDA facilities

Table 4.2: Experiments carried out using INGA and GDA facilities

Sl. no.	User and affiliation	Title of the experiment	Experimental set up	No. of shifts
1	Mr. Mohd. Shariq Asnain Aligarh Muslim University	A study of fusion incompleteness in heavy-ion interactions at low energies	GDA-GPSC	12
2	Ms. Madhu IIT Roorkee	High-spin spectroscopy of neutron-deficient TI and Ir isotopes	INGA-LaBr	11
3	Ms. A. Choudhary Lucknow University	Study of Nb and Mo isotopes	INGA-LaBr	12

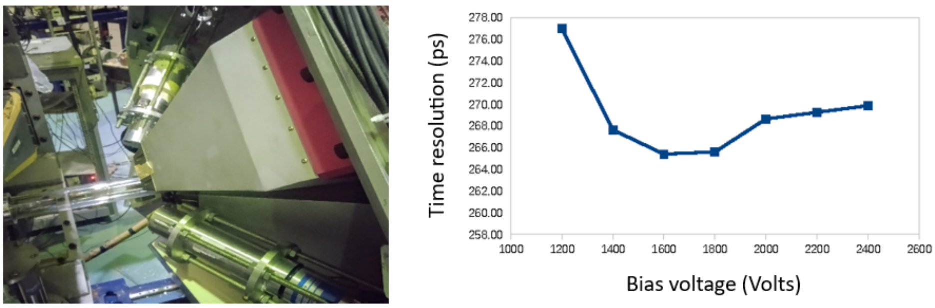

Figure 4.1: LaBr detectors mounted in the INGA array (left) and time resolution as a function of bias voltage for a $2'' \times 2''$ LaBr detector.

4.2.3 New developments

4.2.3.1 Addition of LaBr detectors to INGA setup

Yashraj[1], I. Bala[1], U. Ghosh[1], Mohit Kumar[1], A. Jhingan[1], Mamta Jain[1], Naresh[1], Madhu[2], Dhananjay[2], Kuldeep[3], A. Deo[2], S. Sihotra[3] and R. P. Singh[1]

[1] *Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India*
[2] *Department of Physics, IIT Roorkee, Roorkee 247667, India*
[3] *Department of Physics, Panjab University, Chandigarh 160014, India*

Five LaBr detectors were added to the INGA array for measurement of half-lives of excited nuclear states in the sub-nanosecond range. The crystal dimensions for four detectors were 2 inch in diameter and 2 inch in length. Two detectors each were contributed by IIT, Roorkee and Panjab university. The fifth detector used from IUAC detector laboratory was 1.5 inch × 1.5 inch in dimension. Fig. 4.1 (left panel) shows a picture of the setup in the INGA. The detectors and the electronics were first tested and optimized in the GDA before installation in the INGA. The best time resolution obtained was about 265 ps with ^{60}Co gamma source. In the right panel of Fig. 4.1, time resolution as a function of bias voltage is shown for the optimised parameters of CFD delay and walk using an Ortec TAC module. The face of LaBr detectors were about 12 cm from the target.

4.2.4 LaBr simulation study

Prince Yadav*, Yashraj[1] and R. P. Singh[1]

*Project student
[1] Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India

A simulation study using GEANT4 simulation toolkit was performed to get the response of sixteen $2'' \times 2''$ LaBr detector array placed in the forward cone of INGA. Response of the detector parameters such as energy resolution, efficiency, hit, peak-to-total were studied as a function of gamma-ray energy for ^{137}Cs, ^{60}Co and ^{152}Eu radioactive sources placed at the INGA target position. Fig. 4.2 (left panel) depicts the arrangement of 16 LaBr in the forward cone with 8 clover detectors in the backward hemisphere. Further efforts are in progress to include ACS detectors and the support structure in the simulation study. The right panel of Fig. 4.2 shows a simulated spectrum for ^{60}Co source. Photo-peak efficiency of LaBr array was estimated to be about 3.3 % at 1.17 MeV and estimated cross-talk between LaBr detectors were about 2.2%.

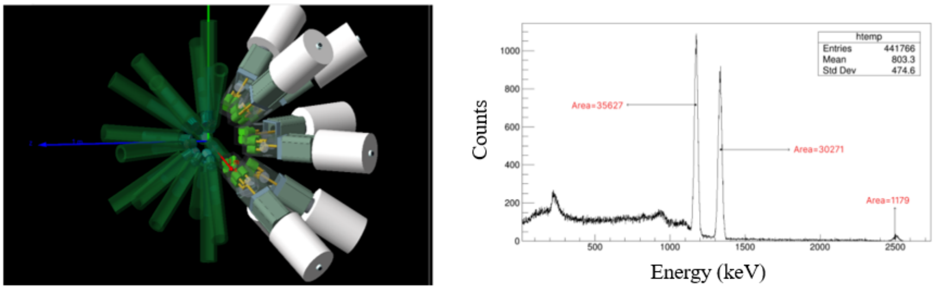

Figure 4.2: Simulated arrangement of 16 LaBr detectors ($2'' \times 2''$) in forward hemisphere and 8 Clover detectors in the back hemisphere of INGA (left) and hit spectrum of LaBr detectors for the arrangement shown in the left panel. The source used in simulation was ^{152}Eu.

4.3 Recoil separators

4.3.1 Heavy Ion Reaction Analyzer

S. Nath, J. Gehlot, Gonika, T. Varughese and N. Madhavan

A split-anode, deep ionization detector has been developed and commissioned at the focal plane of HIRA facility (Fig. 4.3), beyond the large area, Multi-Wire Proportional Counter (MWPC). The detector has a depth of about 40 cm, split into four anode segments of 5 cm and the remaining three of 11 cm, with a dead section of 2 cm. The detector was operated at 75 mbar pressure of isobutane gas with 0.5 μm thick mylar foil as the window separating this detector from the MWPC. The MWPC too has a 0.5 μm thick mylar entrance foil and was filled with isobutane gas of 5 mbar pressure. After successful testing to rule out any leak, the ionization detector is being tested with α-particles from a ^{241}Am source. Subsequent tests with fission fragments and beam are planned.

A list of user experiments carried out in the HIRA is given in Table 4.3.

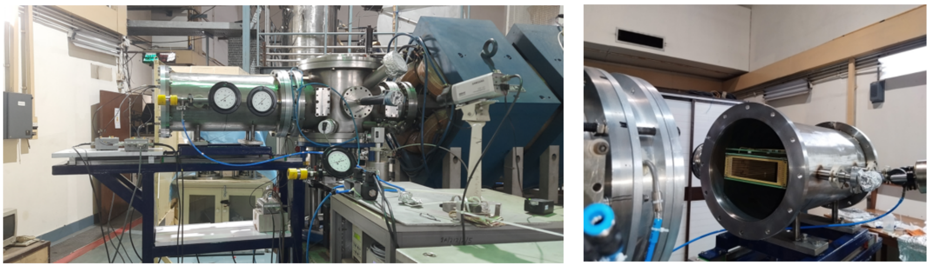

Figure 4.3: Deep Ionization detector commissioned at the HIRA focal plane beyond the large MWPC detector (left) and deep Ionization detector slid on the LM rails exposing the window foil.

Table 4.3: Experiments carried out using the HIRA in the last academic year

Sl. no.	User and affiliation	Title of the experiment	No. of shifts
1.	Chandra Kumar IUAC	Fusion and quasi-elastic measurements for the systems ^{28}Si+^{140,142}Ce above as well as below the Coulomb barrier	18
2.	Amar Das Gauhati University	Quasi-elastic measurements for the systems ^{16}O+^{116}Sn,^{178}Hf,^{176}Yb	18
3.	Chandra Kumar IUAC	Transfer measurements for the systems ^{28}Si+^{140,142}Ce around the Coulomb barrier	15

4.3.2 HYbrid Recoil mass Analyzer

N. Madhavan, S. Nath, J. Gehlot, Gonika and T. Varughese

HYRA was used in gas-filled mode in several experiments (see Table 4.4) either as a stand-alone facility or in conjunction with the TIFR 4π spin spectrometer facility utilizing beams from the Pelletron+SC-linac.

Table 4.4: Experiments carried out using the HYRA in the last academic year

Sl. no.	User and affiliation	Title of the experiment	No. of shifts
1.	Amninderjeet Kaur Panjab University	Fusion measurements for the system ^{48}Ti+^{124}Sn above as well as below the barrier	18
2.	Phurba Sherpa Delhi University	ER cross-sections and spin distribution measurements for the system ^{48}Ti+^{160}Gd	18
3.	Phurba Sherpa Delhi University	ER cross-sections and spin distribution measurements for the system ^{30}Si+^{178}Hf	18
4.	Ashna B. Central University ofKerala	Fusion measurements for the system ^{30}Si+^{182,184}W	8
5.	Malvika Sagwal IIT Roorkee	Fusion measurements for the systems ^{32}S+^{138}Ba,^{154}Sm	9
6.	Ashna B. Central University of Kerala	Fusion measurements for the systems ^{28}Si+^{182,184}W	7

The following developments are planned in the HYRA, subject to availability of funds, to augment its capability and to utilize beams from the high current injector:

(A) A large aperture, room-temperature quadrupole doublet magnet with accessories and highly stable power supplies,

(B) An advanced focal plane detector system for recoil decay tagging involving advanced position-sensitive silicon detectors, electronics and read-out system and

(C) A rotating target system and a rotating window or windowless distributed pumping system to fully exploit the full configuration of HYRA and the planned high intensity beams from the high current injector.

4.4 Materials science facilities

A. Tripathi, D. Kabiraj, F. Singh, V. V. Sivakumar, S. A. Khan, I. Sulania, S. K. Kedia, R. C. Meena and A. Mishra

The Materials Science facilities are supporting research programmes of a large number of users from different Universities and research Institutions. There were nearly 31 beam time spread over 111 shifts carried out for Materials Science Users. Experiments related with Ph.D programmes of research scholars continue to get priority and 18 such experiments were performed this year.

4.4.1 Materials science beamline in beam hall I

A. Mishra, I. Sulania, S. A. Khan and A. Tripathi

Most of the materials science irradiation experiments are performed in Beam hall irradiation chamber. This year 24 user experiments spread over 101 shifts took place in this chamber. All the sub-systems in this line including irradiation chamber and associated systems are functioning normally and there was no beam time loss due to any breakdown in this beamline.

4.4.2 Materials science beamline facilities in beam hall II

Sanjay K. Kedia, Fouran Singh and Ambuj Tripathi

The beam hall-2 is specifically designed and developed to perform the in-situ irradiation experiments, including in-situ X-ray diffraction, in-situ micro-Raman, in-situ high-temperature irradiation, and in-situ XRD in controlled gas environment for various materials and thin films grown and/or modified by energetic ions at various densities of electronic excitations. In situ measurements hold a distinct advantage over ex-situ measurements due to the elimination of sample-to-sample variations and the capability to conduct measurements without exposing the sample to ambient conditions. This year, we efficiently executed three high-temperature irradiation experiments at ~ 1000 K, for three distinct users by utilizing a total of 15 shifts of the beamtime.

4.4.3 Centre for materials characterization and measurement

A Mishra, R. C. Meena, S. K. Kedia, I Sulania, S. A. Khan and A. Tripathi

A new Centre for Materials Characterization and Measurement (CMCM) is being established at IUAC which will house all the offline facilities for the materials characterization and measurement at one place. The area for CMCM in LEIBF building of IUAC was renovated and the identified instruments were moved to the respective assigned places this year. The reorganization of characterization and measurement facilities including shifting of many equipment such as E beam set up, Solar simulator, FTIR, UV-Vis-NIR spectrophotometer, UV-Vis spectrophotometer, Contact angle measurement setup, Optical microscope, and Photoluminescence setup was implemented. A dark room for optical measurement facilities was also initiated and is nearing completion.

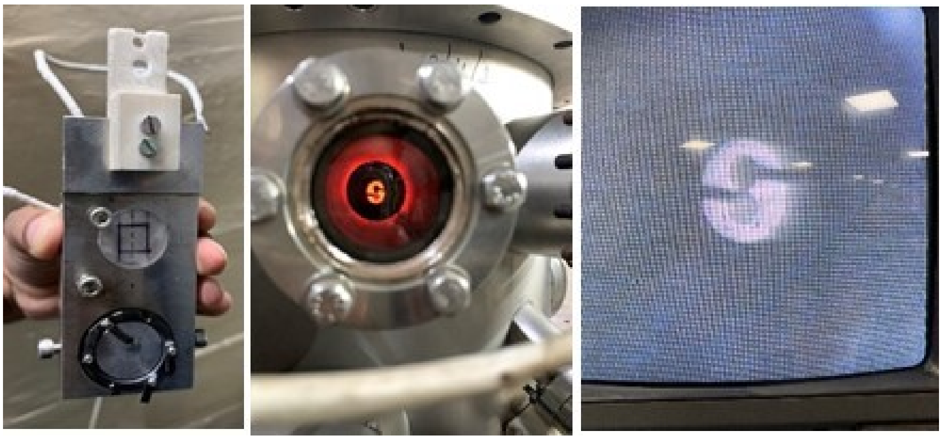

Figure 4.4: Illustration of the various steps of the high-temperature irradiation experiments, wherein samples are affixed onto a one-inch circular surface of a high-temperature cylindrical heater, elevating the sample temperature to 1000 K in a high vacuum environment and the radiant glow of the heater is observable through a vacuum viewing port through viewing camera.

Figure 4.5: CMCM area with thin film deposition facilities after reorganization.

Figure 4.6: Transport measurement setups after reorganization in CMCM area.

4.4.4 Materials synthesis and microscopy facilities

I. Sulania, S. A. Khan, V. V. Siva Kumar and Ambuj Tripathi

The laboratory has equipment such as Ball Milling system, ECR plasma system, Optical Microscope, UV-Vis Spectrophotometer, Contact Angle measurement set-up, Scanning Probe Microscope system, Scanning Electron microscope with EDAX attachment and Coater for SEM. While some of these have been in working condition and were utilized by IUAC user community belonging to different universities/institutes, a few facilities needed extensive maintainence or repairs. Efforts are being put to get new equipment and also to replace those falling into disuse.

4.4.4.1 Scanning electron microscope

S. A. Khan, I. Sulania and A. Tripathi

In the first week of May 2023, noise began to emerge in images from TESCAN's MIRA II LMH Field Emission Scanning Electron Microscope (FE-SEM). Service engineers from TESCAN's authorized company in India made multiple visits to address and rectify the issue. Although the noise was significantly reduced, it still occurs sporadically. Consequently, throughout most months of this year, the facility was primarily employed for compositional analysis using the attached Oxford Instruments dispersive X-ray Spectroscopy. A total of eighteen users from twelve different institutions were able to characterize 76 samples using the facility.

4.4.4.2 Scanning probe microscope

Indra Sulania and Ambuj Tripathi

Most of the Scanning Probe Microscope modes such as AFM, MFM, C-AFM, STM, STS and F-d mode etc are available at IUAC and used in user experiments. The facility has been running for over 20 years satisfactorily yielding to many publications. Last year around Sept. 2023, it developed a problem with the scanner dragging (Fig. 4.7) and the software for the Realtime imaging did not boot.

Presently, due to obsolete nature of the equipment, it is not been supported by company and therefore, not in working conditions. However, some of the user support performed with it 2023-24 is as follows: 75 samples characterized for 19 users in AFM/MFM mode.

Figure 4.7: Scanner dragging.

4.4.4.3 Optical microscope

Indra Sulania and Ambuj Tripathi

The laboratory has a high-end Optical Microscope from Zeiss, which can magnify the images up to 100x. It is mostly used as a tool to predetermine the sample's area before performing the SPM measurements. It is especially useful to track the single or multilayer graphene flakes etc. The Optical Microscope system was utilized for characterizing 02 samples of 01 users.

4.4.4.4 The UV-Vis spectrophotometer

Indra Sulania and Ambuj Tripathi

UV-Vis Spectrophotometer, which was procured from Hitachi, is capable of doing measurements in Absorbance/ Transmission mode. The UV-Vis spectrophotometer was used to characterize 60 samples of 04 users. The set-up is working satisfactorily and no major maintenance was required.

4.4.4.5 Contact angle measurement facility

Indra Sulania

The laboratory has a unique Instrument, Drop Shape Analyzer, DSA100, from Kruss GmbH, Germany. It is a high-quality system for knowing the wetting and adhesion properties of solid surfaces with water drop. From the basic unit, for precise measurement of the contact angle to the fully automatic expert instrument for serial measurement of surface free energy. When an interface exists between a liquid and a solid, the angle between the surface of the liquid and the outline of the contact surface is described as the contact angle (lower case theta). The contact angle (wetting angle) is a measure of the wettability of a solid by a liquid. This year, it was utilized by 04 users scanning nearly 60 samples. The set-up is working satisfactorily and no major maintenance was required.

4.4.5 Transport measurement facilities

Ramcharan Meena and Ambuj Tripathi

Various facilities like resistivity, dielectric, Hall effect, IV-CV measurements, and Thermoelectric effects are available in the transport laboratory. Out of these facilities, the Hall effect is available at LN2 and room temperature, while the rest of the facilities are temperature-dependent in the range of 20 K to 450 K. The temperature-dependent measurements are performed using the closed-cycle refrigerator (CCR) and liquid nitrogen-based dipstick bath. The resistivity measurements are performed using the Keithley source meter (2612B) and electrometer (6517B) in four or two probe modes. These measurements can be performed by forcing current or voltage to the sample. These currents and voltage are chosen so that the joule heating effect does not affect the magnitude. The dielectric measurements are performed using capacitance mode in the frequency range of 20 Hz-2 MHz. The Hall effect measurements are performed in Vander Pauw geometry with a magnetic field of 0.57 Tesla. I-V measurements are performed before starting the Hall effect measurements to check the linearity of the connections. The IV-CV measurements are performed using W metal probes, and thermoelectric measurements are performed using a differential method. All the above-mentioned facilities are interfaced with LabView software for automatic measurements. These facilities were calibrated from time to time with standard samples. We also have an in-situ transport measurement facility in Material Science Beam Hall-1; it is used for in-situ electrical resistivity measurements, IV-CV measurements, and device testing under irradiation conditions. These facilities were used by more than 50 users, characterizing more than 200 samples in the previous year.

4.4.5.1 Installation and testing of polarization vs. electric field (P-E) loop measurement setup

Ramcharan Meena and Ambuj Tripathi

A new polarization vs electric field (P-E) measurements facility is installed in the IUAC transport lab, working in the temperature range of RT-200°C. This facility can be used for samples of both types (bulk and thin film). The setup is purchased from M/s. Marine India (Model No: 0.03PE 2MHz 1F) with a capability of external voltage up to ±10 kV. Various measurements include Ferroelectric charge at different frequencies and temperatures, Fatigue measurement, Remnant hysteresis, Curve energy, Leakage current, Current Density, Single Point C/V, PUND measurement, General pulse, and Sample pulse. All these measurements are performed using the automated LabView program. The accuracy during the temperature-dependent measurements is 0.1°C. Both sides of the samples are coated with silver paint and dipped inside the oil to enhance the magnitude of the applied voltage. This setup is calibrated using standard PbZrTiO3(PZT) and BaTiO3 (BTO) samples. The standard graph of the calibration of PZT samples is shown in Fig. 4.8.

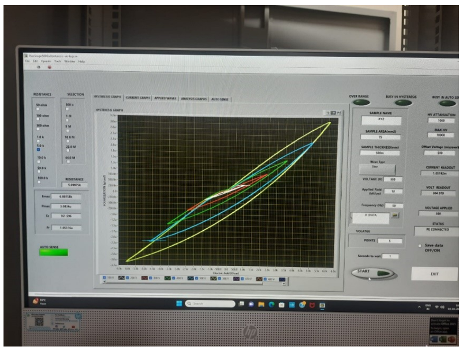

Figure 4.8: Polarization vs electric field (P-E) for various electric fields for PZT samples.

4.4.6 Structure and spectroscopy measurement facilities

Sanjay K. Kedia and Fouran Singh

The laboratory is equipped with several facilities of development and characterizations/measurements of materials namely RF sputtering, e-beam evaporator, tubular furnace, high-temperature furnace, in-situ micro-Raman spectrometer, in-situ X-ray diffractometer, UV-Vis-NIR spectrometer, FTIR spectrometer, UV Photoluminescence setup, solar simulator, etc. These research facilities have been extensively used by the users for many years for their accelerator-based research activities. However, many of them are having aging issues and will be upgraded/replaced in a phased manner with state of art facilities in the coming years. Nevertheless, in the present scenario regular operation and upkeep has become a very challenging issue.

The micro-Raman facility is now operational which has been down for quite some time with the support of service engineer on the old XP based system only and as it is known that XP system has been obsolete long back. Therefore, parts of such equipment will not be compatible with existing windows platform. The issues with system performance have been investigated / inspected and tested the complete system including spectrometer, CCD Detector, microscope and laser for proper functioning. Angle tuned for 514 nm laser filter to get optimize maximum white light transmission. Angle and optimized laser beam through spectrometer and onto the video crosshair for through focus. Aligned and optimized the slit and CCD area to get maximum signal intensity. The system has been calibrated using standard calibration source. The SMPS power supply and mother board of the computer also had problem and been got repaired with the support of local vendor. Some of the pictures of the same is shown below and now system is operational and a few measurements on some samples have been carried out.

Figure 4.9: In-situ micro-Raman microscope, damaged mother board of the computer of the data acquisition and laser alignment etc. in BH-II.

The photoluminescence and solar simulator facility was in operation in lab 205. But for the renovation of room number 205 these facilities have been moved out in open space of the Centre of Materials Characterization and Measurements (CMCM) area and were out of order. However, a dark room along with personnel safety has been made with the support of civil departments and shortly these facilities will also be available for the regular experiments.

4.4.6.1 Upkeep and maintenance of the X-Ray diffraction system

Sanjay K. Kedia, Fouran Singh and Ambuj Tripathi

The in situ and low-temperature XRD system has remained operational for the last 20 years in BH-II despite experiencing aging issues. Up until now, the service and maintenance of the XRD system have been managed internally. Various alarms, faults, chocking of the X-ray tube, and glitches have been routinely addressed in-house. However, this year, we encountered a new issue with the X-ray shutter and its associated electronics started malfunctioning, which could not be resolved in-house.

In response to this issue, we engaged a Bruker service engineer who diagnosed that the electronics associated with the tube stage had malfunctioned, and the X-ray tube counts were relatively low. Consequently, we decided to procure (import) two items: the tube stage along with its associated electronics and a new X-ray tube. Both components have been procured, installed, and the calibration of the machine is currently underway.

Figure 4.10: (Left) The Bruker make D8 Advanced diffractometer, a state-of-the-art in situ and low-temperature XRD machine, installed in Beam Hall-2. (Right) Illustration of the chocked water filter/mesh situated within the x-ray tube of the XRD machine, hindering the cooling of the tube. Employing ultrasonic cleaning successfully cleared the obstructed mesh filter, allowing us to power the tube. The software recorded a water flow rate of 6 liters per minute during this process.

4.4.6.2 Re-installation and utilization of UV-Vis-NIR, FTIR, UV photoluminescence and solar simulator facilities in the dark room of the CMCM area

M. Chahal, Jyoti Yadav, S. K. Saini, Harshvardhan, Raj Kumar, Sanjay K. Kedia and Fouran Singh

The UV-Vis-NIR and Fourier Transform Infrared (FTIR) was in regular operation in the CMCM area for the regular experiments and about 218 spectra from 15 users and 235 spectra from 16 users have been taken using FTIR and UV-Vis-NIR facilities, respectively in the year 2023. The UV-Vis-NIR spectrometer is very stable as shown in the left panel of Fig. 4.11. The system has also been calibrated for the reflectance measurements of films with the help of gold thin film deposited in the Target Laboratory in this year. The reflectance measurement along with reference is shown in the right panel of Fig. 4.11. However, it may be worth noting that for the reflectance studies bigger size thin films are needed for performing the measurements.

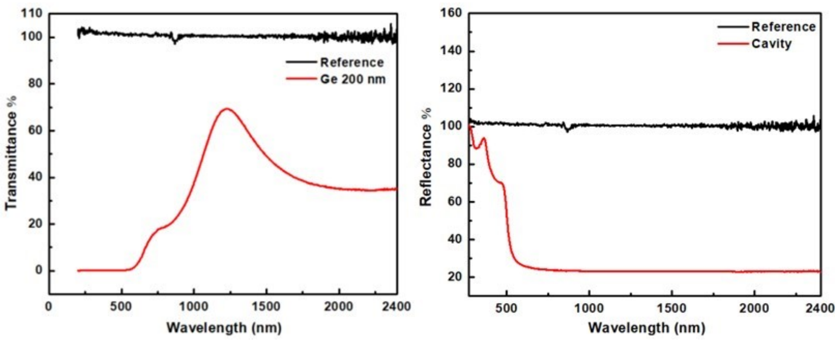

Figure 4.11: (Left) Transmittance spectrum of the sample and reference and (Right) reflectance spectrum from the micro-cavity and the reference for Au- film acquired using Hitachi U-4150 spectrometer.

Similarly, the FTIR spectrometer is in good health as can be seen in the reference spectrum in the left panel of Fig. 4.12 and the spectrum of the sample in the right panel of Fig. 4.12. A partition in the CMCM area for having a dark room is in progress and in the final phase of completion as can be seen in various photographs shown in Fig. 4.13. This will allow re-installation of the UV photoluminescence and solar simulation measurements with spectral sensitivity and personnel safety.

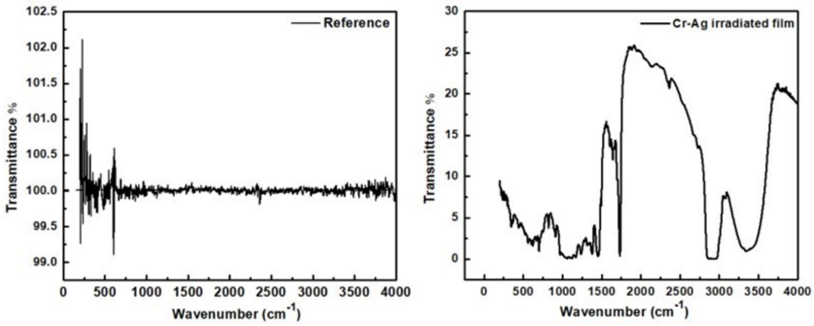

Figure 4.12: (Left) Reference transmittance spectrum and (Right) samples spectrum acquired using the Bruker vortex70 spectrometer.

Figure 4.13: Various pictures of the progress of the dark room, which is almost complete in the CMCM area for performing the UV photoluminescence and solar simulation measurements.

4.4.7 Thin film deposition systems and high-temperature furnaces

Sanjay K. Kedia, Fouran Singh and V. V. Siva Kumar

The sputtering system has undergone upgrades through the replacement or repair of various components, including the temperature controller, substrate rotation mechanism, PID controller, vacuum gauge, thickness monitor, as well as water and air pipes. It is now fully operational in the designated CMCM area. We have provided support to $\sim$ 11 users in fabricating more than 200 thin films using the RF sputtering technique to meet their specific requirements.

Similarly, the evaporation system (Fig. 4.14) is equipped to deposit thin films through both thermal evaporation and electron beam-induced evaporation techniques. In-house diagnostics and resolutions have addressed issues such as a faulty electrical contractor, a malfunctioning chiller, issues with the e-beam power supply, and a bad vacuum gauge. The machine remained fully functional throughout the year, with the exception of a short maintenance period. This year, we have fabricated $\sim$ 20 thin films for $\sim$ 3 different users to support in their research objectives. The synthesis of the films by the sol-gel method has also

Figure 4.14: (Left) Installation of the evaporation (thermal and e-beam) system including the source of the electron beam, power supplies, controller, associated electronics, etc., at the newly designated place in the CMCM building. (Right) Fabrication of the multiple thin films in a single run aimed to minimizing sample-to-sample variation. This was achieved by utilizing the newly repaired 2-inch gun within the RF sputtering system.

been initiated after the renovation work and this is available for the regular use of the users including the in-house users. We have supported several users for preparing their thin film samples from both techniques. The high-temperature furnaces are operating regularly and are utilized by several users for the calcination, annealing, and sintering of their samples across various temperature ranges. This year, we have conducted heat treatments in desired steps for $\sim$ 130 samples, supporting 9 different users.

4.4.8 High-resolution transmission electron microscopy facility

Ambuj Mishra and Debdulal Kabiraj

Energetic ion beams play a crucial role in modifications of the materials and can change their physical properties. TEM is a state-of-the-art technique that is used to investigate morphological, structural, and compositional modifications in a material. The IUAC TEM and TEM sample preparation facilities are being utilized by various users of different universities and research institutes.

4.4.8.1 TEM specimen preparation facility

The TEM specimen preparation facility is equipped with an Ultrasonic bath, Hot Plate, Traditional Lapping/Grinding Tools, Dimple Grinder, Diamond Wire Saw, and Precision Ion Polishing System (PIPS). All these instruments are regularly used for TEM sample preparation. Planar TEM, Cross-sectional TEM (XTEM), and Powder samples on TEM Grids are prepared for TEM characterization. The TEM specimen preparation facility has been utilized to prepare approximately 60 TEM samples including 16 XTEM and 13 planar samples by various users during this academic year 2023-2024.

4.4.8.2 High-resolution scanning transmission electron microscope facility

Maintenance of TEM is very important for smooth operation and is done as and when required. Some of the regular TEM maintenance activities undertaken are the Bake-out process followed by HT conditioning, ACD heating, Camera warmup, etc. TEM Bake-out cycle has been performed in the month of April, May, July and August 2023. More than 80 samples of various users have been characterized for TEM, HRTEM, SAED, STEM-EDS, STEM-EELS, and EFTEM.

4.4.8.3 Upgradation to Gatan GIF continuum ER EELS and TMP-scroll based total oil-free vacuum system in HRTEM

The facility has undergone several upgrades and replacements of components and attachments. The oil-based DP-RP vacuum system has been replaced by an oil-free TMP-Scroll-based vacuum system. The SIP-3 was replaced as it was underperforming due to contamination of the cartridges as it has been continuously in use since June 2018. Upgradation to Gatan GIF Continuum ER EELS has been completed successfully in

December 2024 and the system is regularly in use and is performing satisfactorily. Gatan GIF Continuum ER EELS has various advanced features like 18 μm pixel size CMOS camera equipped with High-speed XCRTM detector technology, target system resolution of less than 0.3 eV, design energy resolution of 0.1 eV, energy range of up to 3000 eV, imaging at full resolution 90 fps and maximum spectral rate 8000 sps. The features of Gatan GIF Continuum ER EELS include high-speed electronic shutter with 0.1 μs speed, 2 kV DualEELS, live STEM-EELS mapping called STEM-SI with 777.U1-STEM pack, real-time zero loss peak stabilization, integrated BF/DF detectors, centred beam stop, and continuous EFTEM.

4.5 Radiation biology

S. A. Khan and A. Tripathi

4.5.1 Radiation biology beamline

The group has a dedicated radiation biology beamline and a laboratory at IUAC. The beamline houses Automated Sample Positioning and Irradiation system for Radiation biology Experiments (ASPIRE) which enables precise and controlled studies of the effects of accelerated heavy ions on biological samples. This system allows for the exposure of cells to specific doses of heavy ions for the studies that are useful for the advancements in cancer therapy and space radiation protection. The beamline's design ensures a uniform dose distribution within 2% standard variation over a circular exposure area with a diameter of 4 cm, crucial for the integrity of the experiments. Two runs were taken in the beamline by Kalyani University group this year for irradiation with 85 MeV Carbon ion beam for the investigation of signalling pathways of activation and secretion of matrix metalloproteinases from lung carcinoma cells after exposure to the carbon ion beam.

During one of the runs, the suction cup which holds the petri dish during irradiation in ASPIRE was broken (Fig. 4.15. It was replaced by the vacuum group during the beamtime within a short time without affecting completion of the experiment.

In this year, four beamtime proposals have been approved by the AUC including one UFR project.

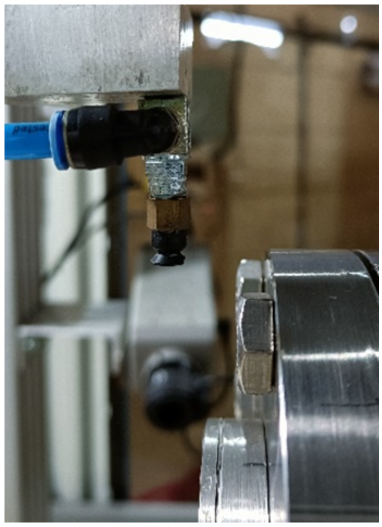

Figure 4.15: Photograph of the broken suction cup attached to the robotic arm in ASPIRE setup.

4.5.2 Radiation biology laboratory

The group is maintaining the lab for facilitating completion of beamtime experiments. The following items were procured for the laboratory this year:

- Microprocessor based pH meter (Eutech PhTutor)
- Consumables: Propanol, Dulbeccos Modified Eagle Medium, Pipette Tips, Fetal Bovine Serum, Nitrile surgical gloves, tissue papers, formaldehyde solution, , dry non-woven disposable wipes
- Multifunction Printer
- Real-time PCR as shown in Fig. 4.16

Figure 4.16: Real-time PCR setup.

4.6 Atomic and molecular physics

4.6.1 Status of vacuum chamber at 75° beam line in LEIBF

D. K. Swami and C. P. Safvan

X-ray spectroscopy experiments pertinent to atomic physics, conducted at low ion beam energy levels, are carried out within a vacuum chamber situated at the 75° beam line in LEIBF. Two silicon drift detectors (SDD) are employed for the measurement of x-rays during these experiments, exhibiting a resolution of approximately 140-150 eV at 5.9 keV. Additionally, two silicon surface barrier detectors are employed to detect scattered and backscattered charged particles. The chamber has the capability to accommodate 4-5 targets concurrently, which can be maneuvered both linearly and angularly using a motion feed-through and a rotatable axis-360° adjustable stage respectively, both affixed to the lid. A collimator (penetrable Faraday cup) is situated at the ion beam entrance prior to reaching the targets. The vacuum level within the chamber during experiments typically ranges between 10^{-6} to 10^{-7} mbar.

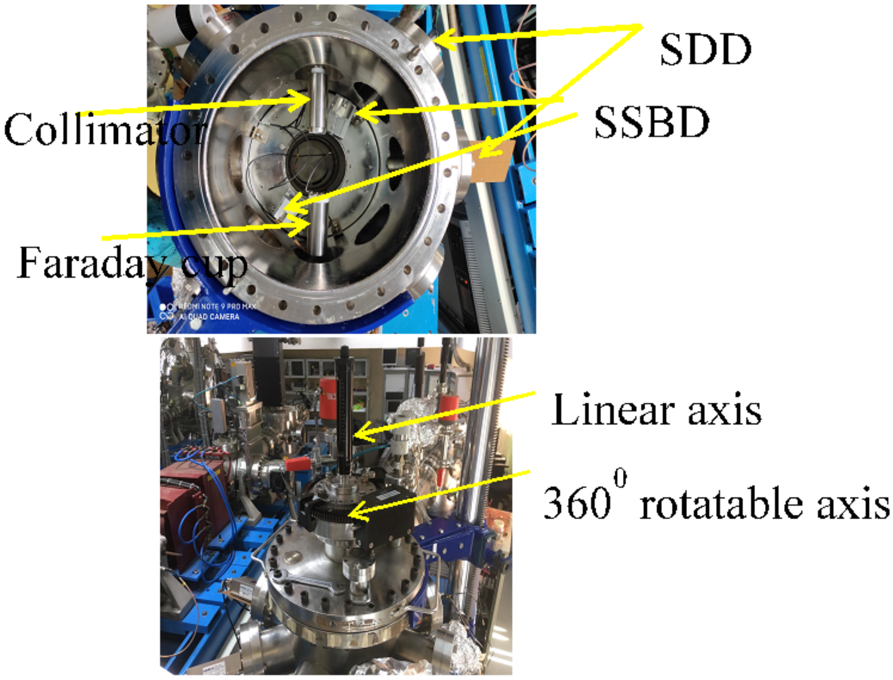

Figure 4.17: top and side view of vacuum chamber at 75° beam line in LEIBF.

4.6.2 Status of general purpose atomic physics vacuum chamber at beam hall-II

D. K. Swami and C. P. Safvan

Experiments involving the collision of highly charged ion beams with solids and subsequent X-ray spectroscopy are conducted in the General Purpose Atomic Physics Vacuum Chamber (GPAC) situated at Beam Hall-II. Within this setup, two silicon drift X-ray detectors (SDDs) are strategically positioned at varying angles relative to the ion beam, offering an experimental resolution of approximately 140-150 eV at 5.9 keV. Complementing these detectors, two silicon surface barrier detectors are utilized to capture scattered and backscattered charged particles. The experiments can accommodate up to 10 targets simultaneously, allowing for comprehensive analyses. To ensure optimal experimental conditions, the vacuum level within the chamber is meticulously maintained between 10^{-6} to 10^{-7} mbar throughout the duration of the experiments.

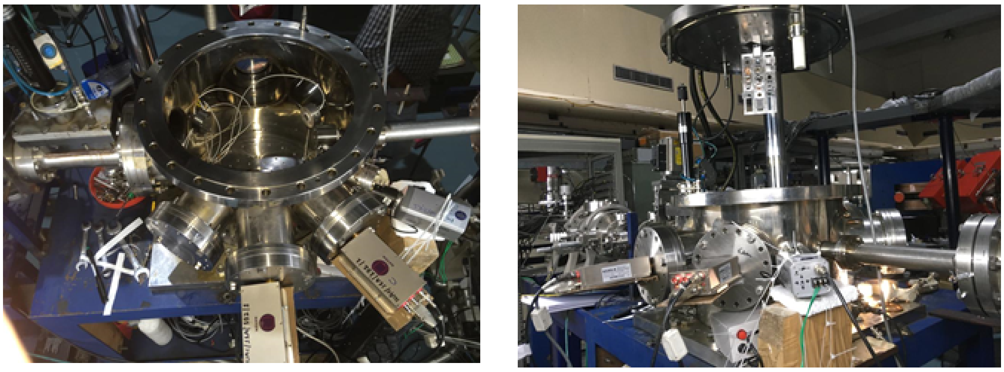

Figure 4.18: Photographs of GPAC in beam hall-II.

4.6.3 A new setup for atom molecule collision in low energy ion beam facility

Aditya Kumar, Pragya Bhatt and C. P. Safvan

A novel experimental configuration has been implemented within the low energy ion beam facility, specifically along the 105-degree line (atomic and molecular physics line). The principal objective of this setup is to investigate the ionization phenomena of atomic and molecular gas targets induced by low energy neutral projectiles. Such interactions hold profound significance in various realms, including interstellar and astronomical studies, where low energy protons, originating from solar wind, interact with the outer atmospheres of celestial bodies, undergoing electron capture and thereby transforming into neutral particles, a process commonly known as proton precipitation. These energetic neutral particle traverse through planetary electric and magnetic fields without deviation until encountering atomic and molecular gases near the planetary surface, subsequently inducing dissociation or ionization.

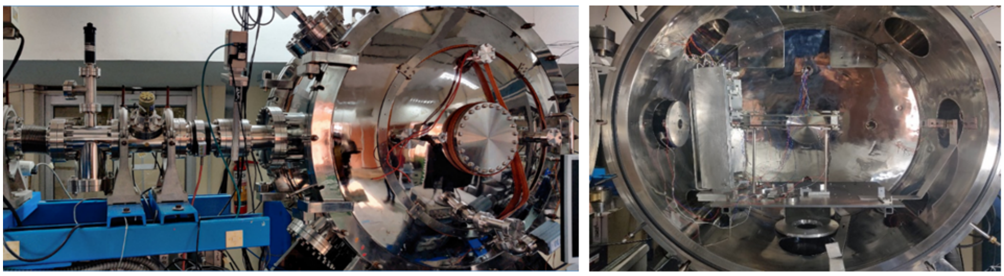

Figure 4.19: Atomic and molecular physics beamline (105°) in low energy ion beam facility. (a) Newly installed gas cell for neutral beam formation. (b) Experimental chamber with new electrostatic separator, shield and TOFMS.

The experimental investigation employs a proton beam projectile with energy spanning from 25 to 150keV. Illustrated in Fig. 4.19, the experimental setup entails the generation of the neutral beam through the interaction of the proton beam (H^+) within an accelerator with nitrogen gas within a newly developed gas cell. Precise regulation of nitrogen gas flow is achieved via a precision needle valve, with the gas cell incorporating ports for both turbo pumps for evacuation during proton beam operation. Subsequent to the gas cell, a collimator of 1 mm diameter directs the neutral beam forward, while a newly devised electrostatic separator eliminates all accompanying charged particles. Any deflected ions are directed towards a grounded metal shield, allowing the unimpeded passage of the neutral beam through a 10mm aperture. Within the experimental chamber, the interaction region comprises the projectile, a gas jet emanating from a grounded needle at room temperature, and a time of flight mass spectrometer (TOFMS), all mutually oriented perpendicularly. Ions and electrons generated during the interaction are spatially segregated by a perpendicular electric field of 400V/cm, with electrons detected employing a channel electron multiplier (CEM) orthogonally positioned to the beam trajectory. Time spectra are acquired for the target gases such as Ar and He under both proton and neutral impact at four projectile energies (25, 50, 100, 150) keV enabling the determination of relative cross section from coincidence yields.