4 EXPERIMENTAL FACILITIES IN BEAM HALL

4.1 GENERAL PURPOSE SCATTERING CHAMBER AND NATIONAL ARRAY OF NEUTRON DETECTORS

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

Fig. 4.1.1: The General Purpose Scattering Chamber (GPSC) installed in 30° beam line after the Gamma Detector Array (GDA) set up.

The General Purpose Scattering Chamber (GPSC) was relocated in the 30° beam line (Fig. 4.1.1) in Beam Hall I. Several user experiments were successfully carried out after the re-installation. One of the user experiments, to study anomalous light particle emission in heavy ion-induced fusion reaction, involved use of a heterogeneous detector set up – multi-wire proportional counters for the detection of evaporation residues (ERs), an array of CsI detectors for the detection of light charged particles like protons and alpha particles and organic liquid scintillators for the detection of neutrons.

4.1.1 List of experiments carried out in GPSC and NAND

The following experiments were carried out in GPSC using Pelletron beam and in NAND using linac beam during the last one year:

User / Affiliation	Experiment	Beam	No of shifts
Dr. Akhil Jhingan IUAC, New Delhi	Facility test for MWPC	^{16}O	3
Ms. Honey Arora Panjab University, Chandigarh	Anomalous light particle spectra in heavy ion induced fusion reactions	^{16}O, ^{32}S	24
Dr. A. R. Khan ISRO, Bangalore	Single Event Effects (SEE) testing on micro circuits	Cl, Ti, Ni, Ag	6
Mr. Munish Kumar Department of Physics, Bareilly College, Bareilly	Study of incomplete fusion dynamics in heavy ion induced reactions at moderate excitation energies	C, O	15
Ms. Devinder Pal Kaur Panjab University, Chandigarh,	Fission fragment mass distribution for the closed-shell nuclei (effect of extra push versus shell closure)	^{48}Ti	15

Ms. Shruti Panjab University, Chandigarh	Fragmentation dynamics and neutron multiplicity measurements for super-heavy nuclei	^{48}Ti	30
Prof. N. M. Badiger Karnatak University, Dharwad	Study of fission dynamics near super heavy region	^{30}Si	15

4.1.2 Development of multi-wire proportional counters for fission studies

A pair of large area (20 cm × 10 cm) position sensitive multi-wire proportional counters (MWPC) have been developed for fission studies induced by heavy ion beams. The detectors were designed with three electrodes geometry in which timing electrode (cathode) is sandwiched between position electrodes. Cathode was developed from double sided aluminised mylar (polyethylene terephthalate) of thickness 2 µm. X position frame was fabricated using gold plated tungsten wires of thickness 20 µm stretched on a 3.2 mm thick PCB. A total of 160 wires were soldered with a pitch of ~1.2 mm and were interconnected using Rhombus fixed delay chips (RZB 12-5) for extracting position information. The Y plane consisted of gold plated copper strips printed on a PCB frame whose width and separation were ~1 mm and 0.25 mm, respectively. As in the case of X frame, all the position strips, 80 numbers, were interconnected using delay chips. The end to end delay in X and Y frame were 160 ns and 80 ns, respectively. The electrodes were assembled in X-C-Y configuration with an inter-electrode separation of ~3.2 mm. The entire electrode assembly was mounted inside a rectangular aluminum chamber and it was isolated from the reaction chamber using a thin window foil (1 µm). A steady flow of isobutane gas (4 – 6 mbar pressure) was maintained inside the detector volume. Both detectors were tested thoroughly with standard radioactive sources such as ^{241}Am and ^{252}Cf.

These detectors are being used for heavy ion induced fission reactions to study mass gated neutron multiplicity in super heavy region. They exhibit excellent time resolution (≤ 1 ns) and appreciable separation of fission like events from beam like particles. Fig. 4.1.2 shows typical width of elastic peak and time of flight correlation observed in one of the reactions studied.

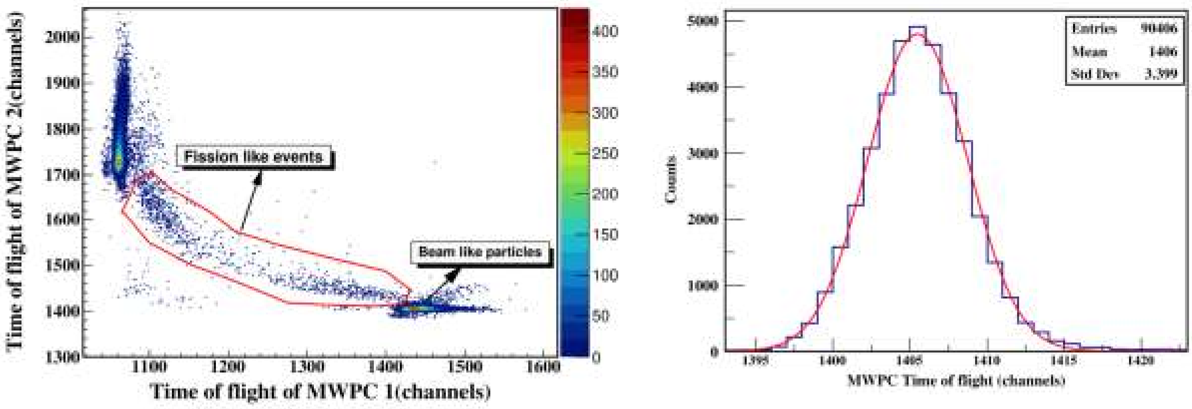

Fig. 4.1.2: Time of flight correlation of events detected in two MWPCs (left) and typical time spread of the elastic peak (right).

4.1.3 Testing of indigenous VME crate controller for NAND data acquisition system

Mamta Jain, E. T. Subramaniam, Kusum Rani, Divya Arora and NAND group

VME based data acquisition has been used in NAND for the multi-parameter data acquisition which includes more than 300 parameters. The existing system has been upgraded with new indigenously developed VME controller ROSE (Readout Ordained Sequencer Engine for VME). It was designed and fabricated in house and gives added advantages of cost effectiveness and ease of maintenance. The data acquisition software developed for the online acquisition of data using the indigenous VME controller, MARS (acronym for Multi-parameter Acquisition with Root based Storage) is compatible with ROOT format, the internationally accepted program for Nuclear Physics and Particle Physics data analysis. This zero-suppressed data acquisition effectively improves the throughput of data collection and reduces substantially the size of data file. A thorough testing of the VME controller ROSE along with MARS has been carried out with standard gamma and neutron sources for long time stability and high count rate handling capacity. After confirming the satisfactory performance of the new system, it has been used in a few user experiments using Linac beam and found to be working satisfactorily

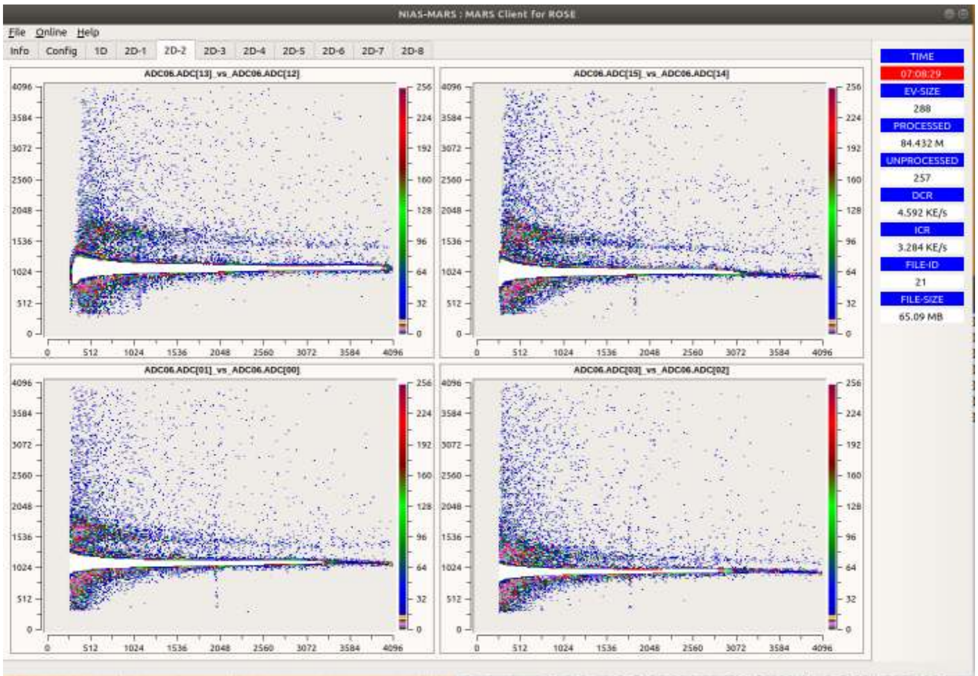

Fig. 4.1.3: MARS GUI display showing PSD versus pulse height (E) spectra for few neutron detectors during online acuuisition.

4.1.4 Measurement of neutron energy distribution for ^{241}Am using NAND

A. T. Fathima Shirin Shana[1], Divya Arora and NAND group.

[1]Department of physics, Government Arts and Science College, Calicut 673018, Kerala, India

^{241}Am-Be radioactive sources are commonly used standard sources for production of fast neutrons. The α-particles emitted from ^{241}Am are captured by ^{9}Be nuclei, which produce neutrons through ^{9}Be(α,n)^{12}C reaction. The α-particles emitted by ^{241}Am lose its energy partially in the source itself depending on the composition of the source material. Moreover, the energy of emitted neutrons depends on the excited state of the residual ^{12}C. Furthermore, the emitted neutrons undergo multiple scattering inside the source. As a result, the energy of neutrons from ^{241}Am-Be source has a continuous distribution. ^{241}AmBe neutron source is widely used in industry (as neutron probe for well logging moisture control, etc) and for medical purposes (radiography, radio chemical investigation, etc). Hence it is of high importance to understand its energy distribution.

The NAND facility has been used for carrying out an exclusive measurement of energy of neutrons emitted from ^{241}Am-Be source. A sealed 100 mCi neutron source is used for the study. The source is placed inside the target chamber of NAND facility. A BaF_2 scintillator was placed inside the target chamber for tagging gammas emerging from the source. One of the neutron detectors of NAND facility, (BC501A liquid scintillator, 5″ diameter 5″ depth, cylindrical cell) is used for the detection for neutrons. The neutron energy is obtained from the measured time of flight (TOF) of neutrons with respect to the the time signal from the BaF_2, which is kept very close to the source. Neutron-gamma discrimination is obtained using the pulse shape discrimination (PSD) by implementing zero-cross technique (Fig. 4.1.4). The measured energy distribution of neutrons has been compared with theoretical predictions and data available in the literature. The large flight path available with NAND enables measurement of neutron energy with better resolution.

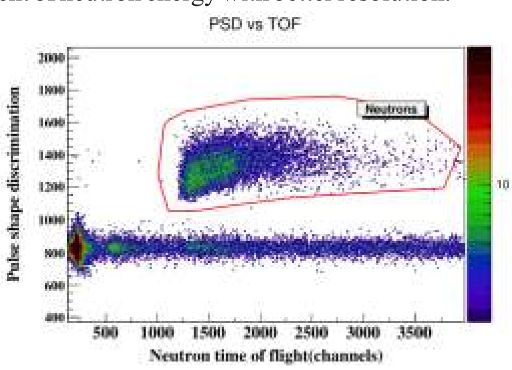

Fig. 4.1.4: A typical PSD versus TOF spectrum.

4.2 GAMMA DETECTOR ARRAYS : GDA and INGA

Yashraj, R. K. Gurjar, Indu Bala, Kusum Rani, R. Kumar, R. P. Singh and S. Muralithar

In the last academic year we added two more Clover detectors to the Indian National Gamma Array (INGA) at IUAC. The detectors were tested for energy resolution, peak-to-total and add-back factor. The energy resolution for each crystal at the INGA beam line was measured to be about 2.1 keV at 1408 keV with a shaping time of 3 μs. The addback factor was found to be about 1.5 and the resolution after add-back was found to be 2.23 keV at 1332 keV. The Clovers were mounted in the INGA array with the Anti-Compton Shield (ACS) detectors.

Clover HPGe detectors are prone to neutron damage while being used continuously in online gamma-ray spectroscopy experiments through heavy ion reactions. Due to this damage, the energy resolution of detectors gets deteriorated with a low energy tail in the gamma-peak. This year, we annealed 12 INGA detectors for approximately two days followed by evacuation for two more days. This improved the energy resolution from 3-4 keV to 2-2.7 keV at 1408 keV. After evacuation, we could achieve inside pressure ~10^{-7} mbar in the detectors. This procedure improved their LN2 holding time.

All the photo-multiplier tube outputs of the new ACS detectors were checked. The energy resolution of the ACS crystals were measured to be about 18 percent for 1332 keV gamma ray. The peak-to-total ratio for peaks of gamma lines from ^{60}Co source, after Compton suppression, was found to be about 40 percent after installing the detectors in the array. About ten experiments were performed with INGA array in 2018-19, each with an average duration of about 15 shifts.

Nineteen inch racks, housing the power electronics for INGA detectors, were moved away from the array. This arrangement helped in creating more working space and reduced chances of LN2 reaching the electronics modules. All the cables were also re-routed.

The last Faraday cup cum beam dump flange was replaced with a new smaller flange and KF coupling. This enabled easy mounting of the Faraday cup flange after mounting the target. The occasional vacuum leak from the last flange was also corrected in the process. The sealing O-rings on the glass chamber were replaced.

Two experiments were carried out for incomplete fusion studies using the Gamma Detector Array (GDA). In one of the experiments, one Clover detector was used. The PAD setup had to be decommissioned to install the General Purpose Scattering Chamber in the GDA beam line.

4.3 RECOIL MASS SPECTROMETERS

4.3.1 Heavy Ion Reaction Analyzer

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

During most part of this year, the Pelletron accelerator was either in long maintenance sessions or operated in conjunction with SC-LINAC in providing beams to Beam Hall-II. In the remaining period, pending experiments using Pelletron beams were prioritized in few other facilities. Hence, no experiment was scheduled in the Heavy Ion Reaction Analyzer (HIRA) facility during this period. HIRA focal plane detector was used by a B. Sc. student as part of IUAC Summer Training Programme. Some of the home-made electronics for HIRA/HYRA facility were tested along with electronics group and later used in HYRA experiments. The cooling water lines of the magnets and power supplies were cleaned and regular maintenance were carried out with the help of MG-II group and Beam Transport Group. All the components, including HIRA rotation option, are in good operational condition. The entire facility was kept covered during civil works such as epoxy flooring and painting of permanent and radiation shielding walls in the area. Exhaustive cleaning of individual components was taken up subsequently.

Three papers were published in Physical Review C based on experiments carried out using the HIRA facility, two on effects of multi-nucleon transfer channels on sub-barrier fusion cross-sections and one to search for stabilizing effects of Z=82 shell closure against fission. One of these was from a Ph. D. thesis experiment of a research scholar from IIT (Ropar), carried out in the previous year, which also led to the award of degree during this year. Several experiments, which are pending for more than two years, will be taken up in the coming year.

4.3.2 HYbrid Recoil mass Analyzer

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

The HYbrid Recoil mass Analyzer (HYRA) facility, in gas-filled mode and using Pelletron + SC-LINAC beams, was used in Ph. D. thesis experiments of research scholars from Punjab University (Chandigarh) and Calicut

University (Kerala) in the evaporation residue (ER) cross section measurements from well above to slightly below the Coulomb barrier in the systems ^{48}Ti+^{140,142}Ce (former) and ^{19}F+^{187}Re and ^{30}Si+^{176}Yb (latter). While the first set of experiments was to study the effect of neutron shell closure on ER cross-section the second set of experiments was to look at entrance channel effects in the formation of compound nucleus ^{206}Po*. Data were collected for similar systems, which are already well-studied, to extract the transmission efficiency of the HYRA in each case. As the Traveling Wave Deflector (TWD) in the Pelletron pulsing system, which is responsible for increasing the time difference between adjacent beam pulses from 250 ns to higher values by factors of two, did not operate at times, a corresponding blank target-frame run was taken to correct for whatever little beam background could exist at the focal plane. The other pending HYRA experiments will be taken up in the next LINAC cycle as the present one had to be terminated abruptly due to the recent pandemic.

Prior to these experiments the following steps were taken up. HYRA was covered during similar exercise of epoxy flooring and wall painting and later the components were thoroughly cleaned. All the magnets and power supplies were serviced. The focal plane MWPC detector system was tested with alpha source. The Data Acquisition System and HYRA control system were tested for longer duration and minor problems encountered were corrected with the help of groups taking care of the same. Some of the electronics developed for data acquisition for HIRA/HYRA facilities were put to use after detailed testing with pulser.

Three Ph. D. degrees were awarded this year for experimental work carried out using the HYRA. Three papers were published in Physical Review C by the respective research scholars. One of these involved the study of ER cross sections and ER-gated angular momentum distributions (using HYRA + TIFR 4π spin spectrometer) over a wide range of excitation energy for the systems ^{16}O+^{208}Pb and ^{18}O+^{206}Pb, both forming the same compound nucleus ^{224}Th*. The other two involved measurement of ER excitation function for the systems ^{16}O+^{203,205}Tl and ^{48}Ti+^{138}Ba and looking for the effect of non-compound fission on ER formation.

4.4 MATERIALS SCIENCE FACILITY

A. Tripathi, K. Asokan, V.V. Sivakumar, Fouran Singh, S.A. Khan, P. K. Kulriya, I. Sulania, R.C. Meena, D. Kabiraj and A. Mishra

The materials science facilities continue to support research programmes of a large number of users from different universities and institutions. This year there were a total of 30 user experiments spread over 102 shifts and were performed without any major beam time loss due to facility break down in materials science beamline in beamhall I. BTA experiments associated with students' Ph.D. programmes continued to get priority with 8 runs spread over 25 shifts were completed. Though the swift heavy ion (SHI) irradiation and related experiments mostly utilize irradiation chamber in the materials science beamlines in beamhall-I, One experiment was performed in the materials science beamline in beamhall-II. Besides this, 2 experiments of 6 shifts requiring low fluence irradiation were performed in GPSC beamline. The details of the experiments being done in areas of SHI induced materials modification and characterization are given in Section 5.2 and releted publication are given in sec 6.7.

Besides irradiation facilities, materials science group is also providing many materials synthesis and characterization facilities such as XRD, AFM, SEM, Raman, UV-Vis, I-V, Hall measurement etc and these are heavily utilized by users. This year more than 2100 samples were characterized.

4.4.1 Maintenance of Irradiation chamber in Beam Hall I

S. A. Khan, R. C. Meena, A. Tripathi,

The beamline with low and high temperature irradiation and in-situ measurement facilities was used by a large number of materials science users and 27 experiments of 92 shifts were performed in this chamber. There were no breakdowns this year and a faulty ion pump was replaced without any loss of user beamtime.

4.4.2 Scanning Probe Microscope

Indra Sulania, Saif Ahmad Khan and Ambuj Tripathi

IUAC has a Multimode SPM system with Nanoscope IIIa controller acquired from Digital Instruments Inc., Veeco (now Bruker) under the IRHPA programme of Deptt. of Science and Technol., India. It is being used extensively in all the modes in user experiments as per the requirement. Most of the SPM modes available are used in user experiments such as AFM, MFM, C-AFM, STM, STS and F-d mode etc. PSD studies for surface growth and Force-Distance studies are also performed. Below is the photograph of the SPM set-up present at IUAC.

This year no major break down occurred with the system. In the regular maintenance, a portable CD driver has been added to give data to users in the CD/DVD after data analysis. A humidity reader is procured to find out the changes (if any) in the humidity readings as the system had undergone major maintenance because of it. SPM instrument is working satisfactorily. This year, total number of samples scanned with SPM are ~ 310 from ~50 users from various Institutes; out of which 280 are with tapping mode AFM, 11 with STM mode and 8 samples with MFM mode..

4.4.3 Tescan MIRA II FE-SEM *with* Oxford INCA PentaFETx3 EDS

S.A. Khan, A. Tripathi

Tescan MIRA II FE-SEM *with* Oxford INCA PentaFETx3 EDS is under regular operation after the computer which had gone bad was replaced last year. This year 527 samples from 74 users from 24 universities/institutes were studied. Besides this EDS study of 470 samples was also carried out.

4.4.3.1 Q150T-S HV Sputter Coater

Q150T-S HV Sputter Coater system is working fine and 184 samples from 46 users were coated with Au/Pd for SEM measurement this year.

4.4.4 Transmission Electron Microscope (TEM)

Ambuj Mishra, Abhilash S R and D Kabiraj

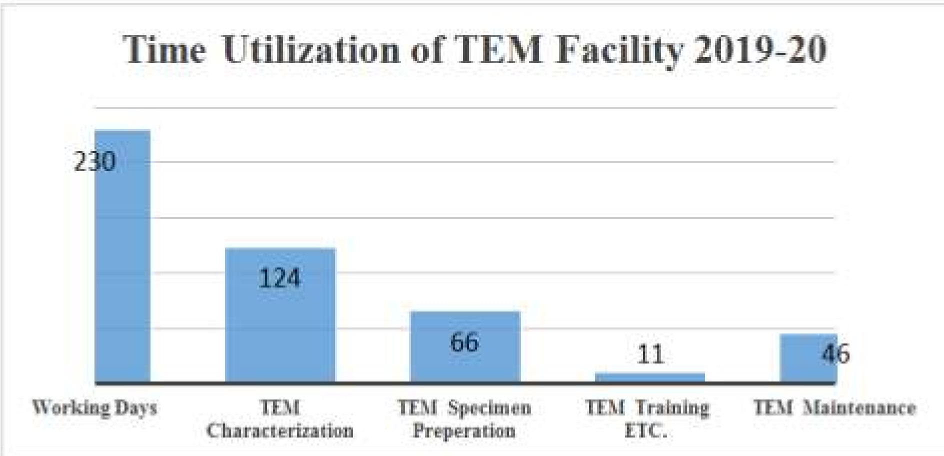

Fig. 1: Time Utilization of TEM Facility 2019-20 (all quantities are in days)

4.4.4.1 TEM Specimen Preparation

TEM specimen preparation facility is equipped with 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. TEM, Cross-sectional TEM (XTEM) and Powder samples on TEM Grids can be prepared here for TEM characterization. This year approximately 70 TEM samples (including 13 XTEM samples) of 23 users from various Universities/ Institutes have been prepared.

4.4.4.2 TEM

TEM is a state-of-the-art technique which can investigate morphological, structural and compositional modifications in a material. The role of IUAC TEM and TEM sample preparation facility has been described herewith which have been used by various users to understand ion beam effect in materials modification. Investigation of morphological, structural and compositional modifications in ion irradiated materials using TEM have been reported . TEM maintenance has been done time to time. TEM maintenance includes many activities like LN_2 filling, Chiller water replacement, Bake-out process, HT conditioning after Bake-out process, ACD heating during weekends, Camera warmup etc. This year TEM bake-outs have been done in September 2019 and February 2020. Each time, after these bake-outs, HT conditioning have been done. Camera warm up has been done in September 2019. All TEM facility Log books, TEM maintenance reports/logs and TEM user data backup have been kept updated time to time. This year approximately 137 samples (including 13 XTEM samples) of 38 users from various Universities/ Institutes have been characterized for TEM, HRTEM, STEM, EDS, Selected Area Electron Diffraction (SAED), and Nano-Beam Diffraction broadly in the following field of research:

(i) Revealing the morphological and structural properties of amorphization/ crystallization at the interfaces of thin films.

For this type of study, cross-sectional TEM (XTEM) sample preparation is very crucial. The region of interest has to be thinned down to electron transparency. To investigate the morphological and structural properties of the interfaces, high-resolution TEM (HRTEM) images has to be recorded and analyzed very carefully. This year approximately 16 XTEM samples have been prepared at IUAC using TEM sample preparation facility. G. Maity et. al. [*G. Maity et al, Journal of Non-Crystalline Solids 523 (2019) 119628, RSC Advances, 2020, 10, 4414*] has investigated the Al-induced crystallization of amorphous a-Si under thermal annealing and swift heavy ion irradiation shown in Fig. 2.

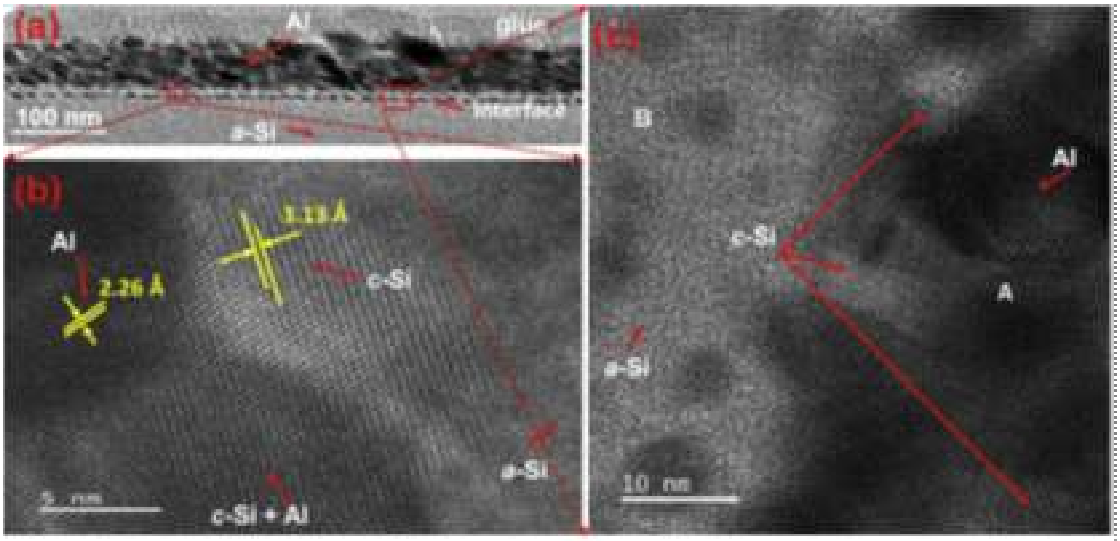

Fig. 2: *(a) Cross-sectional TEM (XTEM) image of a typical sample irradiated with 5×10^{12} ions-cm^{-2} and (b-c) high resolution TEM (HRTEM) images of the same sample [G. Maity et al, Journal of Non-Crystalline Solids 523 (2019) 119628].*

(ii) Study of morphological and structural properties of quantum dots (QDs), nanowires (NWs) and 2D materials

For this type of study, usually samples are prepared on TEM grids. Typically a 200/300 mesh carbon coated copper grid are used for TEM-HRTEM characterizations. The grids are dried completely before inserting it into the TEM column. Budhi Singh et. al. has investigated the wetting behaviour of MoS_2 thin films grown on quartz substrates by chemical vapour deposition (CVD). High resolution transmission electron microscopy (HRTEM) measurement has been carried out to investigate the MoS_2 crystal structural in detail [Budhi Singh et al, Mater. Res. Express 6 (2019) 096424]. In Fig. 3, HRTEM image of MoS_2 with stacked layers has been shown. An interlayer distance has been measured to be 2.1 Å and has been assigned to the (100) plane of MoS_2.

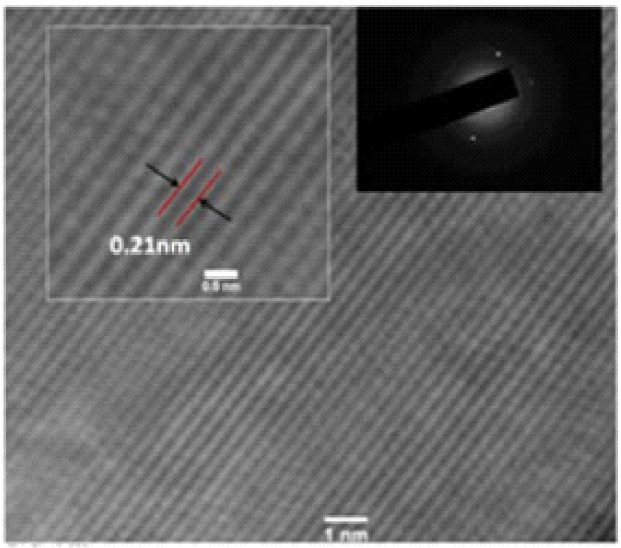

Fig. 3: *HRTEM image of the MoS_2 thin film. An interlayer distance of 2.1 Å is assigned to the (100) plane of MoS_2 [Budhi Singh et al, Mater. Res. Express 6 (2019) 096424]*

Zubair M.S.H. Khan et. al. [Zubair M.S.H. Khan et al, Optical Materials 91 (2019) 386–395], have reported a greener route method to synthesize water soluble nitrogen doped carbon quantum dots (N-CQDs) using red lentils as a precursor through hydrothermal method. Maqsood R. Waikar et. al. has reported the effect of γ-irradiation with 1.25 MeV average energy (Co-60) on the structural, optical and morphological properties of CVD deposited MWCNTs at 10–60 kGy dose [Maqsood R. Waikar et al, Materials Science in Semiconductor Processing 110 (2020) 1049755]. The inter-mingling or agglomeration of the network of nanotubes having varying diameters of about 40–60 nm due to interaction of γ-ray has been confirmed by TEM images shown in Fig. 4.

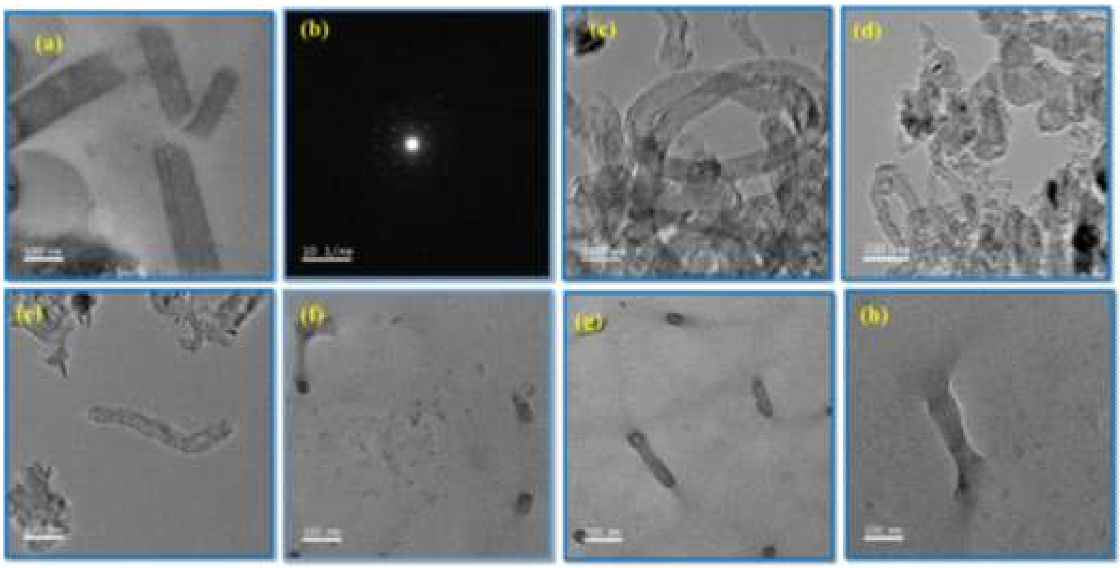

Fig. 4: *The TEM images of (a) pristine MWCNTs, (b) SAED pattern of pristine MWCNTs, and (c)–(h) post γ-irradiated MWCNTs at 10–60 kGy doses [Maqsood R. Waikar et al, Materials Science in Semiconductor Processing 110 (2020) 104975].*

(iii) Study of morphological, structural and compositional properties of thin films and powder samples

For this type of study, generally planar samples are prepared using standard mechanical polishing method using ultrasonic disc cutter, lapping/grinding tool and dimple grinder. Final thinning up to electron transparency is carried out by ion milling of the sample in PIPS system. Sometimes for hard substrate like quartz, glass etc., sample preparation is done by scratching the film gently from the substrate and transferring it on a 200/300 mesh carbon coated copper grid. Deepti et. al. has reported a significant improvement in the hydrogen sensing characteristics of Pd-Au thin film by ion irradiation. The Pd-Au alloy thin film has been synthesized by DC magnetron sputtering and then irradiated by 500 keV Xe^{2+} ion at a fluence of 1×10^{16} ions/cm^2 [Deepti et al, Sensors & Actuators: B. Chemical 301 (2019) 1270067]. TEM of the pristine and irradiated thin films are shown in Fig. 5.

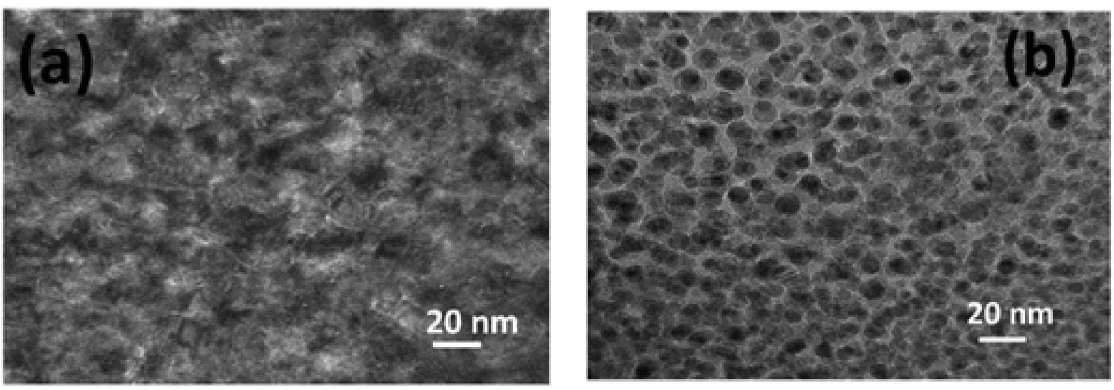

Fig. 5: *(a) TEM image of as deposited, and (b) TEM image of ion irradiated thin film [Deepti et al, Sensors & Actuators: B. Chemical 301 (2019) 1270067]*

Maqsood R.Waikar et. al. has reported the chemically synthesized Zinc Oxide (ZnO) thin films which have been irradiated with the average energy of 1.25 MeV from Co-60 gamma source at different doses for possible applications in NH_3 sensing [Maqsood R.Waikar et al, Journal of Alloys and Compounds 830 (2020) 15464110. The TEM images of pristine and 30 kGy gamma-irradiated ZnO thin film have been shown in Fig. 6(a) and (b), respectively. The nanorods structure of ZnO thin films has been observed. Formation of bunches of nanorods has been confirmed in TEM image of gamma-irradiated ZnO sample which implies that gamma-irradiation possibly controlled the morphology of the materials.

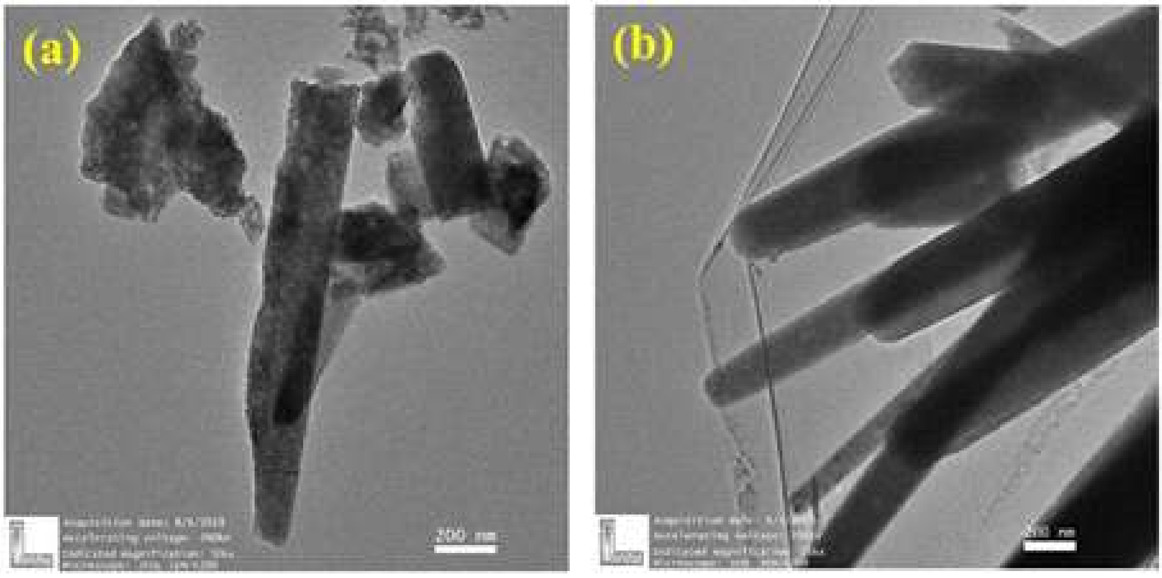

Fig. 6: *TEM images of (a) pristine ZnO thin film and (b) 30 kGy gamma-irradiated ZnO thin film [Maqsood R.Waikar et al, Journal of Alloys and Compounds 830 (2020) 15464110].*

4.4.5 RF sputtering system, dc sputtering system and ball milling system.

V. V. Siva Kumar

The RF parallel plate diode sputtering system was maintained in proper working condition and is being used by users as and when required.

4.4.6 Structure and Spectroscopy Lab

Pawan K. Kulriya and Fouran Singh

The laboratory is having several research facilities for the development and characterizations 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, photo-luminance spectrometer, solar simulator, etc. These research facilities have been extensively used by the many researchers from Indian universities/institutes and aboard working on different types of materials. The facilities are in regular operation besides regular upkeep for research in materials science. *In-situ* x-ray diffraction (XRD) facility has been extensively used for structural characterization of materials. This year offline XRD system has been used for characterization of around 509 samples by 89 users including one *in-situ* run during irradiation. Micro-Raman facility is another heavily utilized facility for the materials characterizations. This facility operates in two modes as *ex-situ* and *in-situ* modes. About 227 spectra were measured for large number users across the country in *ex-situ* mode. The diode laser is procured and replaced the out of order Argon ion laser and facility has been in operation after the installation of this new laser for regular experiments. The other facilities such as UV-photoluminescence and ionoluminescence are in operation for regular experiments. About 88 PL spectra were measured on various types of samples pre- and post irradiation of samples. UV-Vis-NIR and FTIR facilities are also operational for regular experiments and 46 and 194 samples, respectively haven investigated. RF sputtering system has been used for the preparation of thin films of oxide materials. Total 22 depositions have been done by 8 scholars. Among them, one scholar is from IUAC. Electron beam evaporator has been used for preparation of multilayer of various types of materials like $BaCl_2$, Carbon, CaF_2, Pd, and NiCrMn. There are 8 depositions performed in which about 35 samples were prepared. Density measurement balance used for the estimation on the density of the solid materials is procured under the DST-SERB project and after testing this system is being used by many researchers. There are series of good publications based on the utilization of these facilities emerged during this period.

Upkeep and Maintenance of Research Facilities

R.C. Meena and K. Asokan

Presently, most of the facilities are running in good condition. However in the beginning, while replacing the new X-ray generator with existing *in-situ* XRD system; a problem of compatibility was observed and rectified by installing a Universal IO board. In addition, a problem in the compressor unit of cooling unit was noticed and rectified with help of resources available on internet. The vacuum issues in the RF sputtering system were observed and the same is solved by replacing the Pirani gauge with new one. In micro-Raman system a Laser diode has replaced the out of order Argon ion laser and system re-aligned for it efficiency and being in regular operation. Similarly, UV-Vis-NIR after a lot of efforts could be restored back to operation with major maintenance with the help of service engineer. Now, this setup is in regular operation. FTIR spectrometer has also been re-installed for regular user experiments after the civil work in the lab.

4.4.7 Electrical transport and low temperature lab:

R.C. Meena and K. Asokan

There are various facilities available within the Electrical Transport Lab mostly for the measurements of electrical properties of the materials like Resistivity measurement (10K-450 K), Dielectric Measurement (10K-450K), Hall Effect (Room temperature, 80K) and IV-CV measurements for the semiconductor samples. These measurements are possible in the two temperature ranges (1) 10K-300K (2) 80K-450K. Apart from above a 2T magneto resistance setup having measurement temperature range 90K-450K is also available. High resistance measurements are also done with the help of the Electrometer and low resistance measurements with the current source and Nano voltmeter. For dielectric measurements LCR meter is used in the frequency range of 20 Hz to 2 MHz. In this reporting year, over 60 users coming from 25 Indian universities/institutes have characterized more than 300 samples.

There was no major break down in above facilities except the resistivity measurements at the low temperature due the leak in the He supply line of the cryocooler. This supply line will be replaced with a new one shortly. The power supply of the 2T magnet needs replacement of the control module SMD part. The maximum field at the pole gap of 45mm is around 1.7 Tesla. In future, one can plan to do magneto-dielectric measurements with this setup.

There are also some basic facilities for solid state reaction based synthesis of oxide samples. Two furnaces are available that can go up to the 1250 °C both in air and Vacuum ($5*10^{-2}$ mbar). In which one can anneal thin films and bulk powders. The stability is around 3°C. A Rapid Thermal Annealing facility is also available for users.

4.4.8 Contact angle set-up

Indra Sulania and Ambuj Tripathi

The Drop Shape Analyzer from Kruss GmbH, Germany DSA100. It is a high-quality system for knowing the wetting and adhesion on 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 θ. The contact angle (or the wetting angle) is a measure of the wettability of a solid by a liquid. This year, one user has done the measurements on 5 number of samples. The setup is working satisfactorily.

4.4.9 Optical Microscope

Indra Sulania, Saif Ahmad Khan and Ambuj Tripathi

The optical microscope from Zeiss has 5 objectives 5x, 10x, 20x, 50x and 100x and has option of capturing the image through CCD. Overall magnification limit is 1Kx (camera has 10x multiply by highest objective 100x). It is mainly useful to find a smoother area before doing AFM measurements, especially for 2D materials. This year, it has been utilized by 8 users and ~30 number of samples from different Institutes.

4.4.10 UV Visible Spectrophotometer

Indra Sulania and Ambuj Tripathi

The Hitachi Ultraviolet-Visible (UV-Vis) spectrophotometer can scan in the range of 200-1100 nm. The system is working fine and this year, 13 users have used the setup and scanning ~ 216 number of samples from various Institutes. The PC attached to the system had developed a booting problem which was resolved satisfactorily

4.5 RADIATION BIOLOGY FACILITY

A. Sarma

Irradiation Facility: The radiation biology experiments involving accelerated heavy ions are carried out at the dedicated radiation biology beam line of IUAC and utilizing the ASPIRE (automated sample positioning and irradiation system for radiation biology experiments). In this system, the irradiation of cells by accelerated heavy ions can be done at atmospheric pressure with a set of preset doses. The system is characterized by the dose uniformity over a field of 40 mm diameter within 2% standard deviation. The mean fluence is within 1% of the electronically measured value at the centre of the field. The characterization of the system has also been done using irradiated SSNTD [CN 85].

Laboratory Facility: The radiation biology laboratory has the following equipment to facilitate sample preparation and post irradiation treatments:

1. Two CO_2 incubators, two biosafety cabinets, one small laminar flow bench for cell culture,
2. Field inversion gel electrophoresis, normal gel electrophoresis, protein gel electrophoresis set up,
3. Image based cell counter Countess [Invitrogen] which also gives information about cell viability and Beckman-Coulter Z2 cell counter,
4. PCR machine, a crude gel documentation system, UV-Vis spectrophotometer and a fluorescence microscope,
5. Perkin Elmer Multimode Plate Reader, Eppendorf and Plastocraft Refrigerated Centrifuge and a Biotek micro-plate washer.

   Apart from that, LN2 dewars, -80° C ultra freezer, -20° C deep freezer and other refrigerators serve as the storage facilities. The laboratory section has independent split-AC supply isolated from the central AC system. Regular work is going on in the laboratory on analytical procedures involving gene expression studies using PCR, Western Blot, Fluorescence Immunostaining studies etc. by the university users.

The following are the projects which are undertaken at present:

1. Signaling pathways of activation and secretion of Matrix Metalloproteinases from human lung carcinoma cells after irradiation with carbon ion beam (Payel Dey, Kalyani University)
2. Radiosensitization of human cancer cells using G-quadruplex ligands (Sourav Ghosh, Kalyani University)
3. Carbon nanomaterials as cell radiosensitizors in therapeutics (M. Mukherjee, Amity University)
4. Evaluation of radio-protective property of 2,4 di nitrophenol in cellular model against particle radiation (Anant Narayan Bhatt, INMAS)
5. Chromosomal damage induced by high LET carbon beam radiation in comparison to gamma radiation in human peripheral blood lymphocytes / Chinese hamster fibroblast (V79) cells and the effect of diclofenac sodium in modulating it (Amit Alok, INMAS)
6. DNA damage repair kinetics by a potential countermeasure agent using -H2AX / comet assay (Paban K. Agrawala, INMAS)

The following new projects are sanctioned for availing beam time:

1. Differential cellular response to carbon beam in normal versus transformed cells with special reference to mitochondria (Sweta Sanguri, IUAC)
2. Role of autophagy in high Linear Energy Transfer (LET) radiation induced cell death in normal versus transformed cells (Mitu Lal, IUAC)
3. Studies on TLR agonist (mannan) mediated modification in biological radiation response(s) in vitro after carbon beam exposure (Damodar Gupta, INMAS, DRDO)

   Studies on 2-Deoxy-D-glucose capped Gold-coated magnetic nanoparticles (Au@MFe2O4) for transonic and cancer therapy application (Rajesha Nairy K., P. C. Jabin Science College, Hubballi)

4.6 ATOMIC AND MOLECULAR PHYSICS FACILITIES

4.6.1 Status of vacuum chamber at 75^0 beam line in LEIBF

D. K. Swami

Some experiments have been planned in vacuum chamber at 75^0 beam line in LEIBF. One experiment is based on mean charge states measurement. In this experiment, mean charge state is measured of low energy highly ionized atoms passing through thin bilayer targets made up of metals and insulators. Here, aluminized mylar foil will be used as a target. The purpose of this experiment is to find the dependency of mean charge state and the variation in mean charge state on ordering of the target. Another experiment is based on the study of heavy ion atom collision processes in the inverse kinematic system. In the inverse kinematic system, availability of the isotopic pure beams is easier than making a isotopic pure target. So that we can studied isotopic effect on ionization cross section precisely. For these experiments, it is needed to do some modification or added needful things in vacuum chamber, which is required for this experiment. One circular disk with M6 grooves was designed and fabricated at IUAC workshop. This disk is put at the bottom of the chamber for mounting the faraday cups and SSBD detectors. One penetrable faraday cup[1] (with stand) is put in beam axis before target to measure the current and another faraday cup (with stand), which is not penetrable, is put after the target. For the angular motion of the targets, one rotatable axis-360° adjustable stage is mount at the top of the lid. Vacuum inside the chamber is 10^{-7} - 10^{-8} mbar. Now, this chamber is ready for experiments.

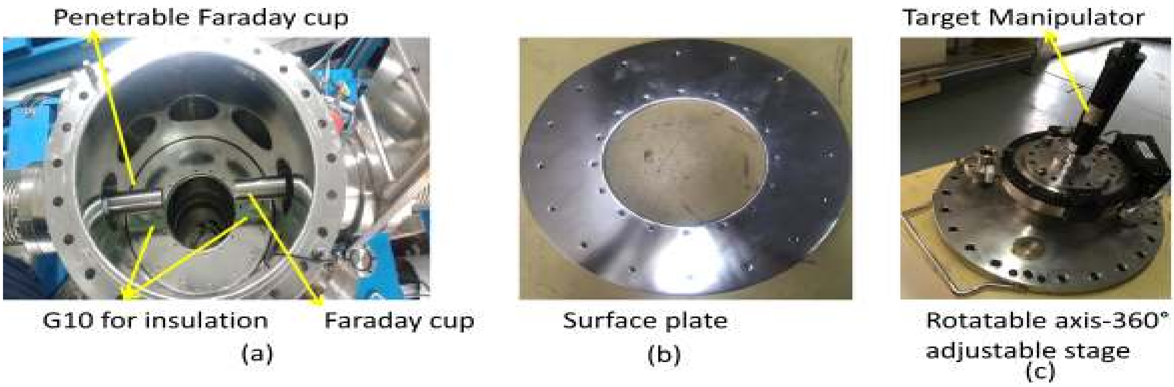

Fig. 4.6.1 Both Faraday cups inside vacuum chamber (b) Surface plate and (c) rotable axis-360^0 adjustable stage.

REFFERENCE

1. Xianming Zhou et. al., Nucl. Instr. Meth. Phys. Res. B 299, 61 (2013).

4.6.2 Developmental work and experiments conducted at LEIBF

C. P. Safvan and Pragya Bhatt

To study the electron capture by the target gas atoms / molecules, a position sensitive dual-micro channel plate detector has been installed (Fig. 4.6.2). The alignment of the axes of the gas jet and the projectile beam is performed. The experimental chamber and the beam line are baked to improve the signal to noise ratio. The projectiles after interacting with the target gas may capture one or more electrons. These post collision projectile ions pass through an electrostatic deflector and get dispersed according to their energies and charge states. These are recorded by the projectile detector (P). A test result for Ar^{9+} ions interacting with neutral Ar atoms is shown in the inset of Fig. 4.6.2.

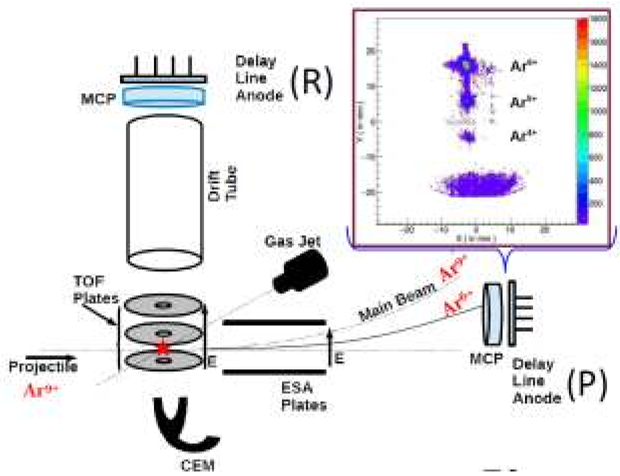

Fig. 4.6.2: Schematic of the recoil ion momentum (RIM) spectrometer with the detector for the post collision projectiles; position spectrum of the projectile ions after interaction with Ar target (inset).

The experiments on the interaction of 50 – 250 kV/q H^+ and Ar^{9+} ions with NO, C_2H_2 and CH_3Cl gas targets are performed using the RIM spectrometer. The analysis of the acquired data is underway. A comparison of kinetic energy released (KER) in the dissociation of CH_3Cl dication under 450 keV H^+ impact is shown in Fig. 4.6.3.

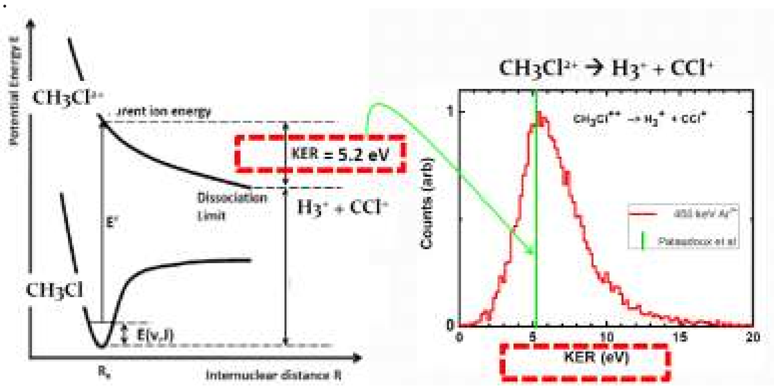

Fig. 4.6.3: Schematic representation of kinetic energy released (KER) in theoretical calculations reported in the literature (left) for the dissociation of CH_3Cl^{2+} into H_3^+ and CCl^+ and its verification in our experiments (right).