4. EXPERIMENTAL FACILITIES IN BEAM HALL

4.1 NEUTRON DETECTOR ARRAY FACILITY (NAND) & GENERAL PURPOSE SCATTERING CHAMBER (GPSC)

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

During the last year we have scheduled many student's thesis experiments and completed all of them successfully. Students from Banaras Hindu University, Panjab University, MSU of Baroda,Visva-Bharati University and Andhra University performed multiple experiments using NAND and GPSC facilities.

Experiment in NAND facility measured fission mass distribution for symmetric and asymmetric fission modes in Thorium compound nucleus and investigation of role of entrance channel nuclear dissipation on neutron multiplicity. 50 liquid scintillators are used to detect neutrons in coincidence with fission fragments detected in pair of large area multi wire proportional counters (MWPC). Pulsed beams from Pelletron accelerator were used in experiments. Fragments velocity distribution and neutron time of flight were recorded online using VME multi parameter data acquisition system. The pre- and post-scission neutron multiplicities were extracted for the reaction ^{18}O+^{186}W at different excitation energies populating the compound nucleus ^{204}Pb to investigate the entrance channel effect on the nuclear dissipation involved in the heavy ion fusion-fission dynamics. The reaction ^{18}O+^{186}W have entrance channel mass asymmetry similar to the reaction ^{16}O+^{181}Ta studied earlier expecting similar behavior from both the systems against the nuclear dissipation. The detailed analysis and results are reported in a recent publication in Phy. Rev. C.

Other experiments performed in GPSC facility aimed to extract barrier distribution using quasi-elastic measurements and influence of breakup like process in weakly bound projectiles. Following experiments have been completed.

1) Quasi-elastic scattering measurements for ^{16}O, ^{28}Si + ^{144} Sm, the thesis experiment of Ms Kavita Rani, Panjab University.

2) Thesis experiment of Mr Saumyajit Biswas, Visva-Bharati University. The experiment measured quasi-elastic scattering using ^{16}O and ^{28}Si beams at Pelletron energies.

3) Thesis experiment of Ms Arshya Sood, I.I.T Ropar. The experiment was performed to explore the effect of breakup channel on fusion around barrier energies using ^{7}Li, beam.

4) Ms Chhavi Joshi, MSU of Baroda performed experiment to study the effect of breakup on the elastic scattering and fusion mechanism of weakly bound projectiles using ^{7}Li beam.

All these experiment used array of gas-Silicon Hybrid detector telescopes mounted inside GPSC chamber and its multi-channel readout electronics. To measure the quasi-elastic back-scattering events four telescopes were mounted in cone geometry at back angle of 173°. The online data collected using CAMAC based Freedom data acquisition software installed in Data room machines.

The preliminary results from some of these experiments are reported in later section of this annual report.

4.2 GAMMA DETECTOR ARRAYS : GDA AND INGA

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

4.2.1 Indian National Gamma Array (INGA)

In the last academic year about ten experiments were performed to study the structure of nuclei at high excitation energy and angular momentum. A total of about 200 shifts of beam time was utilised for these experiments. To enhance the efficiency of the array two more clover detectors were added to the setup. Eleven clover detectors were annealed and outgassed with the annealing setup at IUAC to restore the high resolution of the detectors. Order is also placed for two more Anti-Compton Shield (ACS) BGO detectors to add to the INGA setup. A five day school on “Modern techniques of γ-ray spectroscopy for nuclear structure studies” was organised in IUAC and more than thirty research scholars participated in this school.

4.2.2 LN_2 Filling System

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

New LN_2 sensors (PT100) were installed at the outlet of clover detectors. A new LN_2 control system using industrial modules based on MODBUS standard and RS485 serial back plane for communication was tested. The test system incorporates Graphic user interface (GUI) based on LabView software for control and automation of the filling system. The pilot system has been used successfully for automated filling of 3 clover detectors in the INGA setup.

4.2.3 Gamma Detector Array (GDA)

GDA setup was used for eight experiments (groups from University of Delhi, AMU, Central University of Jharkhand) in the last academic year. Experiments used the HPGe detectors for study of incomplete fusion reactions with heavy ions and in one of the experiments (IUAC) one HPGe detector was used at the focal plane of HIRA spectrometer.

4.2.4 Perturbed Angular Distribution (PAD) setup

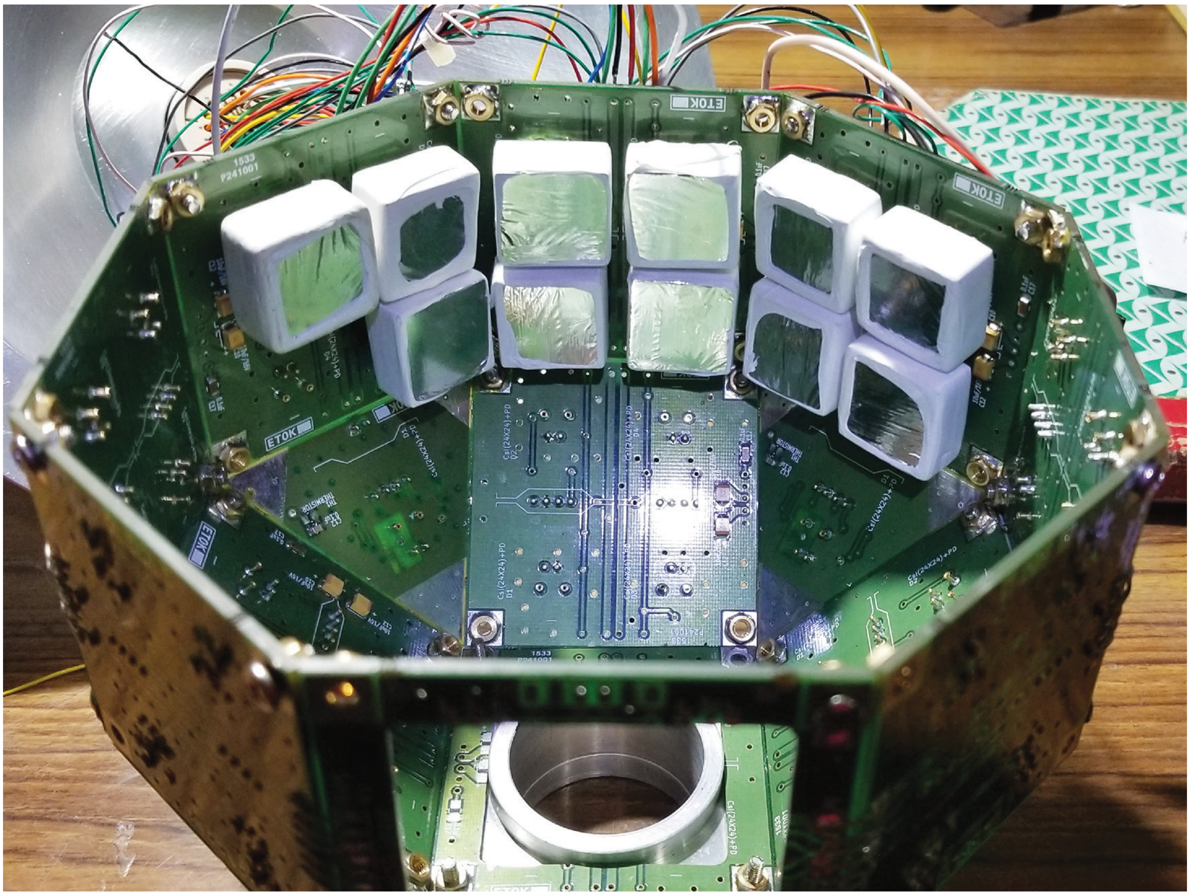
R. Kumar, P. Barua, R P Singh and S Muralithar

The coils for the PAD setup in GDA beam line were refurbished to work with higher magnetic field. The setup is moved to 45º beamline and GPSC is shifted to GDA beamline in the earlier position of PAD setup.

4.2.5 New Charged Particle Detector Array

R. Kumar, Arti Gupta, T. Varughese , S. Venkataramanan and R. P. Singh

Eleven CsI detectors for light charge particles were mounted and tested with alpha and gamma sources for detector resolution. Figure below shows a picture of the array. A project to supplement the array with more detectors and the processing electronics was submitted to SERB for funding.



4.3 RECOIL MASS SPECTROMETERS

4.3.1 Heavy Ion Reaction Analyzer (HIRA)

S. Nath, J. Gehlot, Gonika, T. Varughese, A. Jhingan, N. Madhavan

Last year HIRA was used in five user experiments all of which were related to thesis work and two facility tests were taken up by IUAC personnel.

Measurement of Evaporation Residue (ER) and quasi-elastic backscattering cross-sections in $^{12,13}C$ + ^{197}Au reaction were carried out (Naba K. Ghosh et al., Calcutta University) to study the Collective Enhancement of Level Density (CELD) effects. Survival of ERs as a function of entrance channel mass asymmetry and neutron numbers in colliding partners was studied (P. Jisha et al., Calicut University) by measuring ER excitation function for $^{16,18}O$ + $^{182,184,186}W$ systems. Barrier distribution through ER excitation function was studied (Nabhendu K Deb et al., Guwahati University) for the systems $^{16,18}O$ + $^{61,62}Ni$,^{106}Sn) to understand transfer channel coupling in sub-barrier cross-section enhancement. Measurement of evaporation residue (ER) cross sections for ^{16}O + $^{142,150}Nd$ were carried out (A. Vishakh et al., Central University of Kerala) above and below the Coulomb barrier in order to study fusion reactions forming medium heavy compound systems and the role of target deformation. ER cross sections for the reaction ^{37}Cl + ^{68}Zn were measured (Amit Chauhan et al., IIT-Roorkee) above and below the Coulomb barrier, for studying production optimisation of neutron deficient radio-nuclides of noble metals in low energy reactions. Sub-barrier fusion in ^{37}Cl + ^{130}Te system, for which data was collected in the preceding year, has been published in Physical Review C.

In the facility tests, ER cross-section measurement deep below the one-dimensional barrier in ^{19}F + ^{181}Ta system was attempted (S. Nath, et al., IUAC) through detection of characteristic online gamma rays from the ERs using a germanium clover detector and mass distribution of fission fragments from the fusion of ^{12}C + ^{235}U was undertaken with encouraging results.

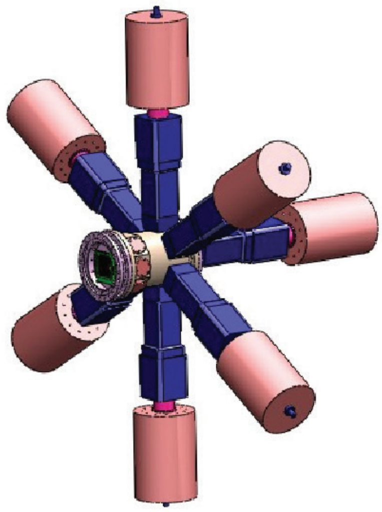
Electronics laboratory, IUAC has developed electronic modules such as Time to Amplitude Converter (TAC), multi channel fast pre-amplifiers to be used with the multi-wire proportional counters. These electronic modules were tested for their functioning with the detectors, as and when they were fabricated. Ms. Gonika won one of three prizes for best presentation in SERB School on Nuclear Astrophysics at SINP, Kolkata. Two research scholars, who used HIRA for their experiments earlier, obtained their Ph. D. degrees during this period.

4.3.2 HYbrid Recoil mass Analyzer (HYRA)

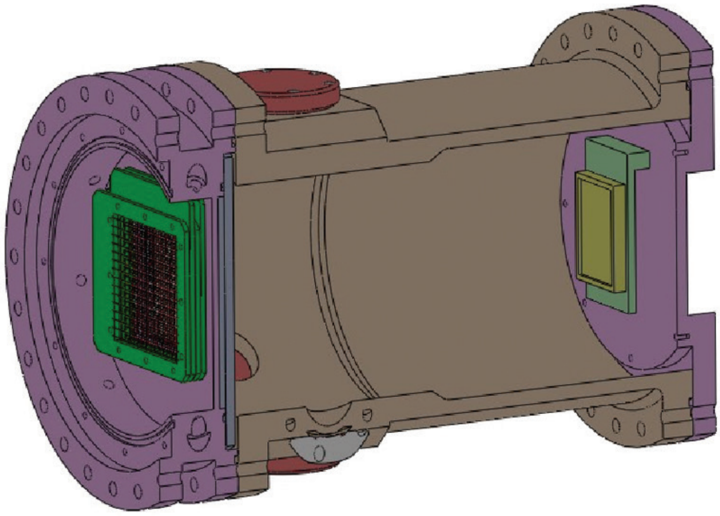
N. Madhavan, S. Nath, J. Gehlot, T. Varughese, Gonika, A. Jhingan

As the SC-LINAC accelerator did not operate during the past year, only two experiments which needed Pelletron beam energies were taken up using HYRA. ER excitation function and angular momentum distributions were measured (M. M. Hosamani et al., Karnatak University) for ^{16}O + ^{208}Pb and ^{18}O + ^{206}Pb, both leading to same compound nucleus (CN) $^{224}Th^*$, to study entrance channel effects in fission hindrance. The analysis of experimental data have been completed. In the other experiment, ER excitation function were measured for ^{16}O + $^{204,206}Pb$ and ^{18}O + $^{204,208}Pb$ systems (P. Sandya Devi et al., Andhra University) from near barrier energy upwards. Earlier, in mid-2017, the higher energy points for these experiments had been measured using Pelletron + SC-LINAC beams. The pending experiments in HYRA are planned to be taken up when SC-LINAC beams are available which is expected to be during the last quarter of 2019.

The new focal plane detector chamber for the planned isomer decay setup, to be used with gas-filled mode of HYRA, has been designed and fabricated. It will allow up to seven germanium clover detectors to be installed close to the silicon detector in which ERs will be implanted. The final flange and the chamber wall have been machined to be thin enough to minimise gamma attenuation in the direction of the longitudinal and the six radial detectors, respectively. Servicing of the MWPC detector cab be done from the front-end after isolating the chamber from HYRA while the silicon detector can be accessed from behind after removing the detector in the longitudinal direction. The compact MWPC detector is being fabricated. All electrode frames have been made and fabrication of wire frames will begin shortly.



Design of new focal plane detector chamber and seven clover germanium detectors



View of the planned MWPC detector and the silicon detector for detection of ERs

Two research scholars, who used HYRA for their theses experiments earlier, have obtained their doctorate degree during the past year and three more are in the process of submitting their theses. Analysis of the experiment to look for Pairing Vs. Clustering of two neutrons in ^{18}O, by using the vacuum momentum achromat mode of HYRA, has been completed and manuscript has been finalised. Experimental observations on ER excitation function in ^{16}O + $^{203,205}Tl$ systems have been published in Physical review C and two manuscripts based on experiments using HYRA are being communicated.

4.4 MATERIALS SCIENCE FACILITY

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

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 63 user experiments spread over 202 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 18 runs spread over 53 shifts. 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, 5 experiments of 23 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.

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 57 experiments of 178 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, A. Tripathi

The SPM has been running without any major problem this year. The two very old CRT computer monitors associated with the system developed a problem and were replaced.

The monitor associated with the microscope, for initial viewing of the sample, was also changed. The settings for balancing the vibration isolation table had got disturbed after a nitrogen cylinder change and the same was restored.

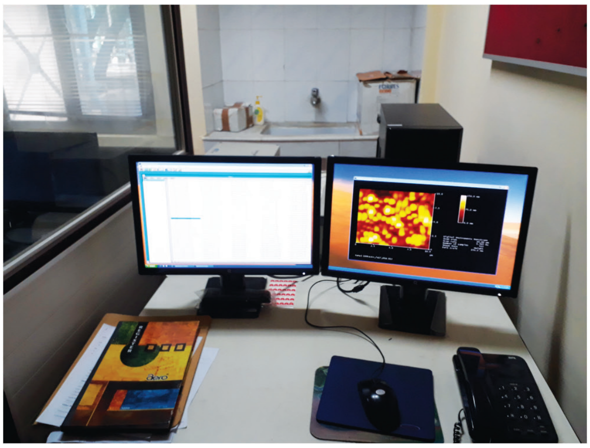


Figure 1: SPM monitors

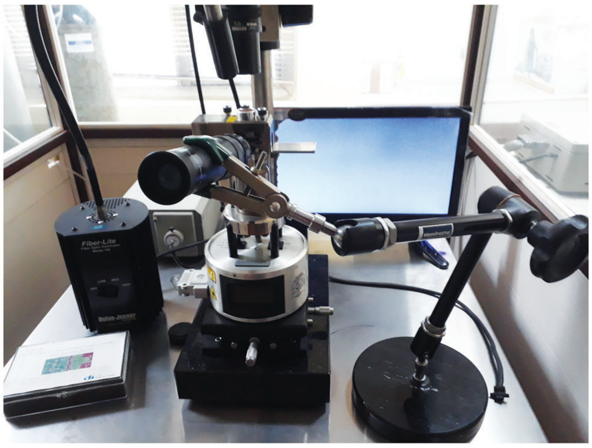


Figure 2: SPM set-up with Optical Microscope for sample viewing

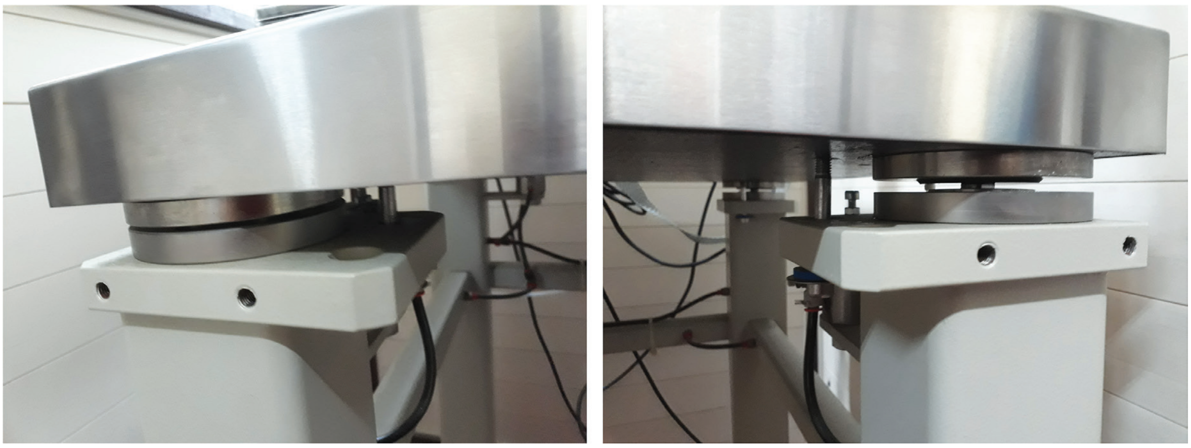


Figure 3: Vibration Isolation Table with adjusting screws

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 a new electron emitter (Denka TFE) was installed in Feburary, 2017 (after ~75000 hrs of operation). Last year (Feb 2018), the computer which had gone bad was procured from TESCAN Brno and was replaced. It has since been working without any major problem. This year new batteries (12V,18Ah,4 nos) were also procured. After replacement of computer, 331 samples of 56 users were characterized. Above numbers are for the period August 17 to July 18. Additionally, 300 samples from 69 users were analyzed between August 2018 to March 2019.

4.4.3.1 Q150T-S HV Sputter Coater

Q150T-S HV Sputter Coater system is working fine and 315 samples from 46 users were coated for SEM measurement for the period August 17 to July 18. Additionally, 152 samples from 28 users were analyzed between August 2018 to March 2019.

4.4.4. 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. A substrate heater was installed and tested. The system was used for thin film deposition work of copper oxide (25 films, IGU, Rewari) and zinc oxide (48 films, Dayalbagh Educational Institute, Agra). The DC sputtering system was used for deposition of thin films of CuO (10 films, IGU, Rewari), Ti (15 films, Kurukshetra university), pure and Al doped $ZnSnN_2$ (~100 films), MgO (5 films) and Cu-Cu_2O (4 films, GGSIPU, Delhi). The pure and Al doped $ZnSnN_2$ films were grown by the user from Bharathiar University, Coimbatore, with different deposition conditions for two different ion beam studies involving Al ion implantation and Ni ion irradiation while Cu-Cu_2O films were grown for gamma irradiation work. The images of plasma formed due to Cu and Zn-Sn sputtering are shown in Fig. The ball milling system was used to pulverize thermo-luminescent materials by user from University of Delhi and LiF and MgF_2 material by user from AIIMS, Delhi (11 times).

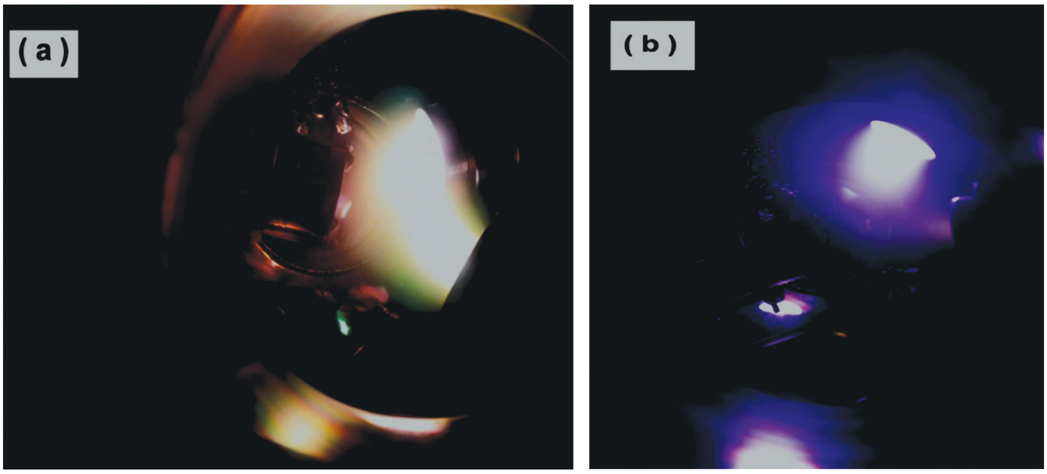


Figure: Images of plasma formed due to (a)Cu sputtering and (b) Sn , Zn sputtering.

4.4.5 Structure and Spectroscopy Laboratory

Pawan K. Kulriya and Fouran Singh

There have been several experiments besides regular upkeep and utilization of the structure and spectroscopy facilities 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 400 samples. Last year, X-ray generator stopped functioning due to problem in its electronic circuit which was not repairable. Therefore, a new X-ray generator was procured and replaced old generator with new one. Similarly, we have also replaced scintillation detector with new detector. An in-situ experiment, in which structural characterization was carried out during ion irradiation, was also performed. Another facility namely high-temperature irradiation setup also exists in the same beamline and one experiment were performed by keeping the target at elevated temperature during swift heavy ion 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 670 spectra were measured for large number users across the country in ex-situ mode. Presently, laser is out of order and order of the procurement of new laser has been placed and probably facility will be operational after the installation of new laser for regular experiments. The other facilities such as UV-photoluminescence and ionoluminescence are also operation and being utilized for regular experiments. About 188 PL spectra were measured on various types of samples pre- and post irradiation of samples. UV-Vis-NIR facility is also got operational for regular experiments, which was down for some time. Solar simulator facility for the characterizations of solar cells and photo diodes is also operational. RF sputtering setup is being in regular operation and about 28 depositions have been carried out by various users. We are happy to inform that few new facilities has been implemented such FTIR, e-gun evaporation and high temperature furnace

4.4.6 High Temperature Furnace and Electron Beam Evaporator System

P.K. Kulriya

Two new research facilities: (a) high-temperature furnace and (b) electron beam evaporator system for the preparation of the thin films (Figure 1) were established this year. Electron beam based thin films evaporator unit is consisting of (a) high vacuum chamber equipped with Pfeiffer (Hipace 700) turbo molecular pump and Alcatel ACP dry pump, (c) substrate holder cum heater with PID controller for 500 oC (d) Inificon quartz crystal thickness monitor and (e) evaporator electrode assembly for the evaporation of two materials.

Figure 1. Photograph of the Electron beam based thin films evaporation system (a) water chiller (b) Control unit and (c) thin film coating setup.

Another facility is a high-temperature furnace which can be used to carry out sintering of the materials up to a temperature of 1700ºC in the ambient condition. Both systems were successfully installed, commissioned and are being used extensively.

4.4.7 Electrical Transport and Low Temperature Laboratory

Ramcharan Meena, Anha Massarat, Anuradha Bhogra, Razia Nongjai, Ashish Kumar, K. Asokan

There are various experimental facilities available in the transport lab that allows one to measure room temperature as well as temperature dependent physical properties of materials. The major facilities are listed below along with their working temperature range and the method of measurements.

Sr No.	Measurement Facility	Temp Range	Method of measurement
1	Resistivity Measurement (Ohm-Giga Ohm Range)	10 K -450 K	2-Probe. 4-Probe
2	Dielectric Measurement	10 K -450 K	Capacitance Method
3	Seebeck Effect	85K- 450 K	Differential Method
4	Hall Effect	300K& 80K	Hall effect Method
5	I-V, V-I	10 K -450 K	Pressure probe Method
6	A.C. Susceptibility	10 K -300 K	Induction Method
7	C-V	85K- 450 K	Capacitance Method
8	High temperature dielectric	300K-1100 K	Capacitance Method

Above mentioned facilities are routinely used by mainly university users and also in house experiments. Last year approx. over 100 users have utilized these facilities. Apart from the above, there are three furnaces that can operate in the temperature range up to 1250 ˚C and other minor facilities that are used for sample preparation. One of these furnaces can be used for the purpose of vacuum annealing having pressure of the order of $3*10^{-2}$ mbar.

A dedicated Rapid thermal annealing set up operating in the temperature range up to 1000 ˚C is also operational. The ramping rate can be up to 60-80 ˚C/S. There are four medium available for the annealing (Vacuum, O_2, N_2, Ar_2). The pressure of the gas can be varied up to range 0-1000 SCCM. In last year, RTA has been used by 15 users.

This lab also supports the in-situ measurements in the Materials Science Beamline and in last year there were 4 *in-situ* temperature dependent electrical transport measurements: I-V, C-V, and R-T.

4.5 STATUS OF THE RESEARCH WORK DONE IN THE RADIATION BIOLOGY FACILITY

A. Sarma, IUAC, New Delhi

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] system. 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 irradiating SSNTD [CN 85].
The radiation biology laboratory is having the following equipment to facilitate the 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, LN_2 Dewars, -80C ultra freezer, -20 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) Investigation of DNA Repair Pathways and cross talk between PARP-1 and P53 after C ion irradiation of cultured human cells, [Dr. Utpal Ghosh, Priyanka Choudhury BTA, Kalyani University]

(2) Signaling pathways of activation and secretion of Matrix Metalloproteinases from human lung carcinoma cells after irradiation with carbon ion beam, Payel Dey, Kalyani University

(3) Radiosensitization of human cancer cells using G-quadruplex ligands. Sourav Ghosh, Kalyani University

(4) Carbon nanomaterials as cell radiosensitizors in therapeutics, M. Mukherjee, Amity University.

(5) Evaluation of Radio-protective property of 2,4 di nitrophenol in cellular model against particle radiation. Anant Narayan Bhatt, INMAS.

(6) 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

(7) DNA damage repair kinetics by a potential countermeasure agent using γ-H2AX/comet assay. Paban K Agrawala, INMAS

4.6 ATOMIC AND MOLECULAR PHYSICS

4.6.1 Modification of Vacuum Chamber at 75º Beam Line in LEIBF

D. K. Swami[1], Shashank Singh[2], S.K. Saini[1] and T. Nandi[1]

[1]Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi-110067, India.
[2] Physics Department, Panjab University Chandigarh, 160014, India

Several experiments have been approved line in LEIBF. For example: One experiment is based on mean charge state measurement using a very simple but novel method [1]. In this experiment, mean charge state will be measured for highly ionized atoms passing through thin bilayer targets made up of metal and insulator. Here, aluminized mylar foil will be used as a target. The purpose of this experiment is to find the dependency of mean charge state on ordering of the target. Another experiment is based on the study of heavy ion solid collision processes in the inverse kinematics so that so that we can study isotopic effect on ionization cross section precisely compared to that with direct kinematics where impurity problem in target is difficult to avoid. For these experiments, some modifications were required in vacuum chamber at 750 beam line. One circular disk with M6 tapped holes place at the bottom of the chamber was designed and fabricated in order to mount the two Faraday cups one in front (penetrable) and other at back of the target along the beam axis. This system acts as beam collimation along with mean charge state measurements [1]. Once the Faraday cups are made aligned, the surface plate is fixed using a certain arrangement. For the angular motion of the targets, one rotatable axis-360° adjustable stage is mounted at the top of the lid and a multi target holding ladder on it. This arrangement will let us keep either metal or insulator of the bilayer target at the exit side.

(a) G10 for insulation Faraday cup

(b) Surface plate

(c) Rotatable axis-360° adjustable stage

Fig 1: (a) Both the Faraday cups inside vacuum chamber are mounted on the surface plate, (b) surface plate and (c) target manipulator on a rotatable axis-3600 adjustable stage.

REFFERENCE

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

4.6.2 Design of Ion Trap Facility for the Life Time Measurement of The Atomic Metastable States

Sugam Kumar, C.P. Safvan and Lekha Nair

An ion trap facility is under development in the Low Energy Ion Beam Facility (LEIBF) at IUAC for the measurement of the life time of the metastable states in the atomic and molecular system. The highly charged ions will be selectively captured and trapped in their metastable states from the ECR ion source. The decay of the metastable state is measured in isolation at low energy, without any active cooling. The ion trap is designed to accept externally produced ions of all species and charge states. The proposed experimental user facility will allow to benchmark corresponding radiative life time measurements with high significance and with broad range of ions species.

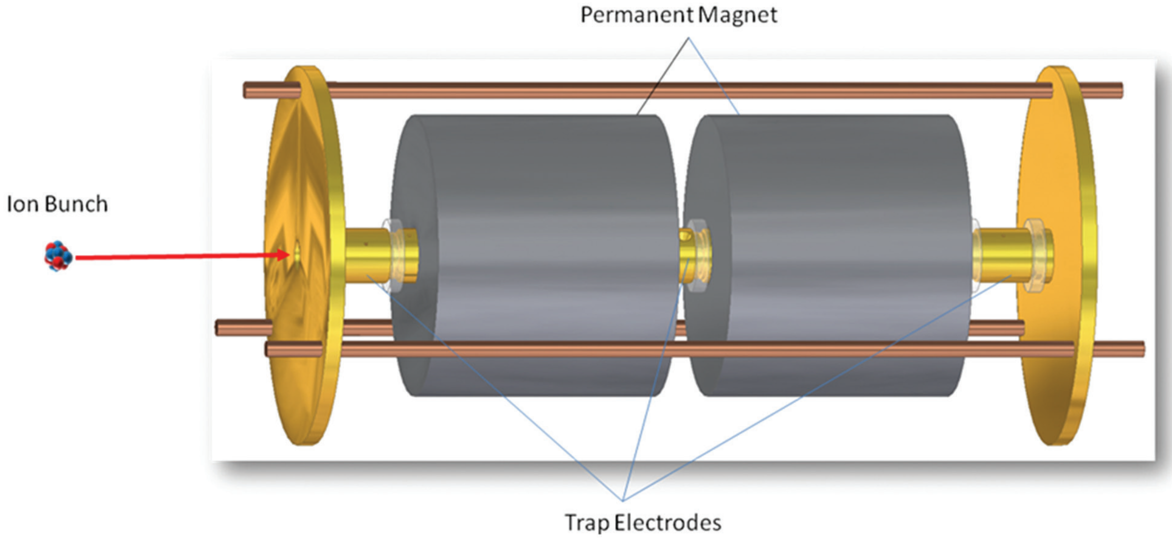


Figure 1: Schematic of the ion trap electrodes assembly with permanent magnet.

A mixture of charge state is extracted from the ECRIS and ejected in an ion pulse. An analyzing magnet in the beam line selects out the desired ions of specific *m/q*. The selected ions are of high kinetic energy and cannot be trapped into the Penning trap, to slow down the ions they are passed through a decelerating system which is already installed in the LEIBF beam line. The energy of the ions is reduced to few eV from few keV, which makes them idea to be captured 'on the fly' into the Penning trap. The transit time over the $\approx$ 20 m beam line from the ECR ion source to the Penning trap would < 50 μs for most of the highly charged ions, much shorter than the radiative lifetime to be measured which is of the order of $\approx 10^{-3}$ s. The ECRIS in combination with the analyzing magnet and decelerating system enable to select the desired charge state of the ions and capture them into the Penning trap with a few eV energy distributions without any active cooling scheme. The lower energy contributes to reduction of systematic errors in the lifetime measurement. The highly charged ions in the metastable states emits photons when they undergo either, M1, E2, M2 etc. transitions. For the ions of our interest the emitted photons lie in the visible range of the whole electromagnetic spectrum. The emitted photons are collected by the lens system and detected by a photomultiplier tube (PMT) or detected directly by an array of photodiodes known as silicon photomultiplier (SiPM) which is an array of few thousand photodiodes on a chip. The advantage of SiPM is that they can be directly mounted on the holes of the Penning trap ring-electrode for the higher collection efficiency. The life time of the forbidden transition is measured by counting the photons falling on the detector and fitting resultant exponential decay curve.

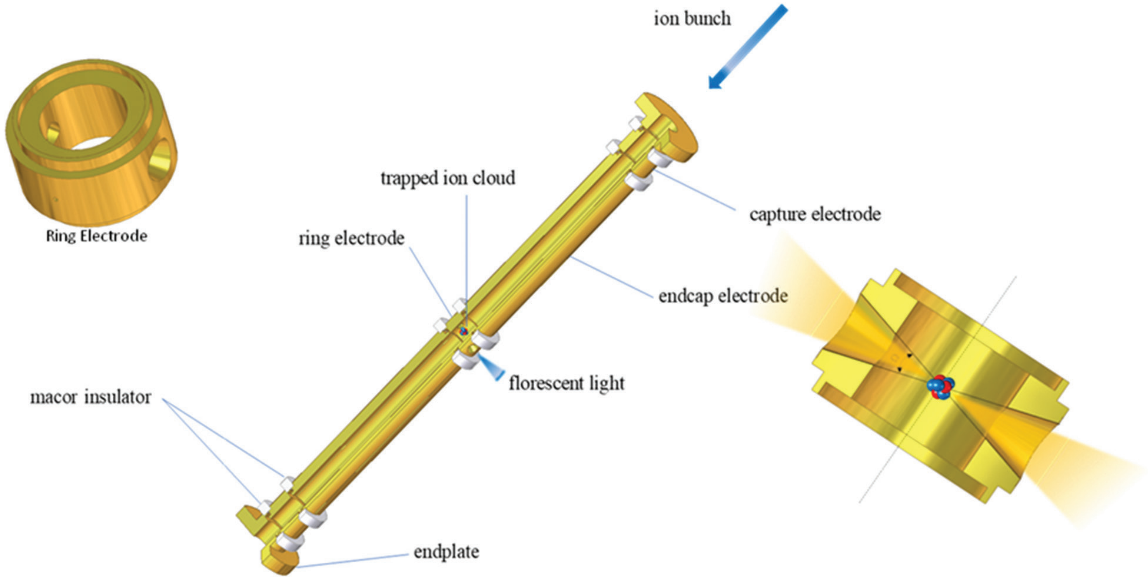


Figure 2: Section view of the ion trap electrodes assembly and ring electrode

The experiment is centered around the Penning trap arrangement inside the homogeneous field region of a 0.8T permanent magnet as shown in figure 1. The trap is a cylindrical open-endcap three-pole Penning trap with an additional capture electrode on either end. It confines the ions radially by the permanent magnet's axial field and axially by an electrostatic potential well created by appropriate voltages applied to the trap electrodes. These consist of oxygen-free copper and are gold-plated to avoid oxidization and to minimize electrostatic patch effects. The electrical insulation is guaranteed by Macor rings and sapphire blocks in between electrodes. One of the endcap electrodes is split into two segments to allow magnetron cooling and also for ion cyclotron frequency detection, ion. Ring segment is equipped with a two, diametrically opposite 3.5 mm holes for detection of fluorescence light and are located 4.5mm away from the main trap axis. This diameter was chosen as the maximum size that does not compromise the stability of the electrode segments. They define a solid angle of 0.475 sr, which is a fraction of $3.7*10^{-2}$ out of the total solid angle of 4π as shown in figure 2. The holes offer 100% transmission for photons and create a negligible loss in the harmonicity of the potential.

The trap electronics include, filters for all signal lines going towards the trap electrodes and pre-amplifiers for axial and cyclotron frequency signals going from the trap electrodes. The trap and its electronics are designed for maximum acceptance with respect to capture, storage, cooling and electronic detection of ions. The experimental cycle including ion creation in the ECRIS, transport, deceleration and capture is defined by a control and data acquisition software based on LabVIEW, which uses, amongst others, two digital delay generators and three synthesized function generators to provide the trap electrode triggers, the frequencies for the system clock, ion excitation and laser scan, and controls the SR430 multichannel scalar used for time-of-flight measurements. The trap itself and its cryo-electronics are cooled to liquid helium temperature by the He Cryo-cooler which maintains the 10 K at the magnet, magnet bore and with it the trap and the attached electronics.

The refurbished 0.8T permanent magnet has been acquired from GSI, Germany. The electrostatic simulation and CAD design of the trap electrodes are completed. The manufacturing of the trap electrodes is under process. The assembly and initial testing will be carried out by the next year.

4.6.3 Effect of Tuner on Reflection Coefficient of 10 GHz Nanogan ECR Ion Source Cavity

Kedar Mal

There are several techniques to improve the performance of ECR ion sources, one of the most efficient technique is frequency tuning. A set of measurements with 10 GHz Nanogan ECR ion source has been carried out to investigate the effect of tuner on reflection coefficient and different excited modes of evacuated cavity. In these measurements, the tuner position was varied from 10mm to 15mm in steps of 0.5mm. At each tuner position, the microwave frequency swept in a range of frequency from 7.5 to 10.6 GHz in steps of 2MHz. The dc bias tube was kept out during measurements. Each peak in reflection coefficient graph shows an excited mode either hybrid or TE and TM. To find out different excited modes, frequency domain solver of CST Studio was used to simulate the evacuated cavity. In the simulation, the plasma lens, all parts of rf cube were included. Figure 1 shows measured reflection coefficient at different tuner position. The simulations of cavity at different tuner position are going on.

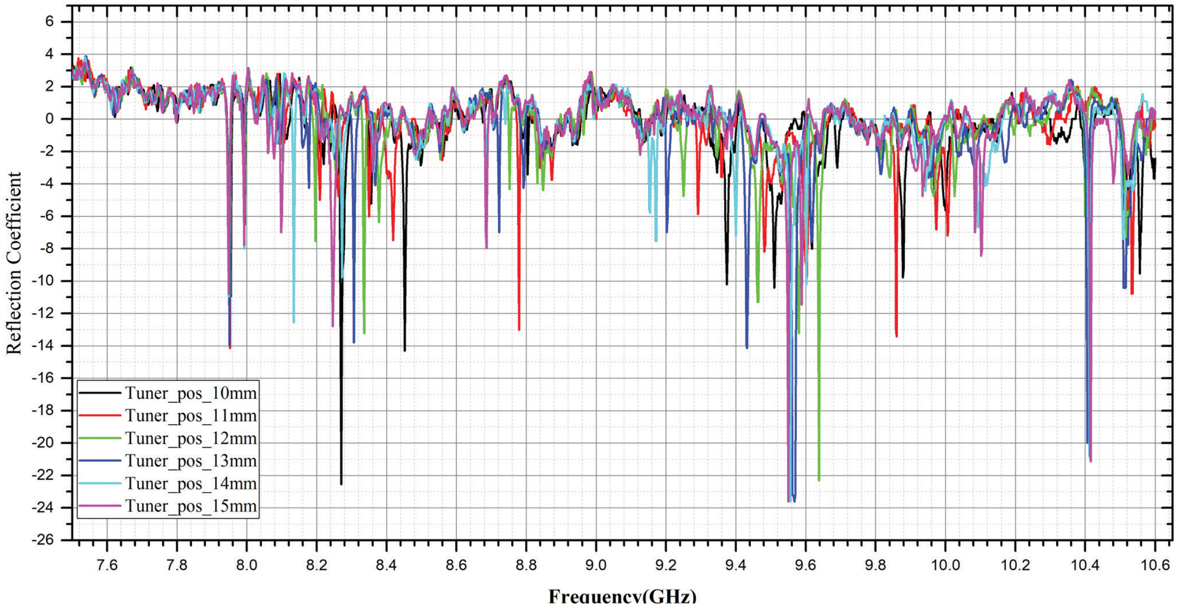


Figure 1: Reflection Coefficient at different tuner position of evacuated cavity

4.6.4 Developmental Work and Experiments Conducted at LEIBF in Atomic and Molecular Physics:

Pragya Bhatt and C P Safvan

(1) A new experimental setup is installed recently in the 105º beam line in LEIBF to study ion induced molecular dissociation. To improve the vacuum of this system, two additional turbo molecular pumps have been installed; one in the beam line and the other in the main experimental chamber. Further, a new provision for heating the chamber has been made. These two additions have helped in improving the vacuum of the beam line and the chamber by one order of magnitude.

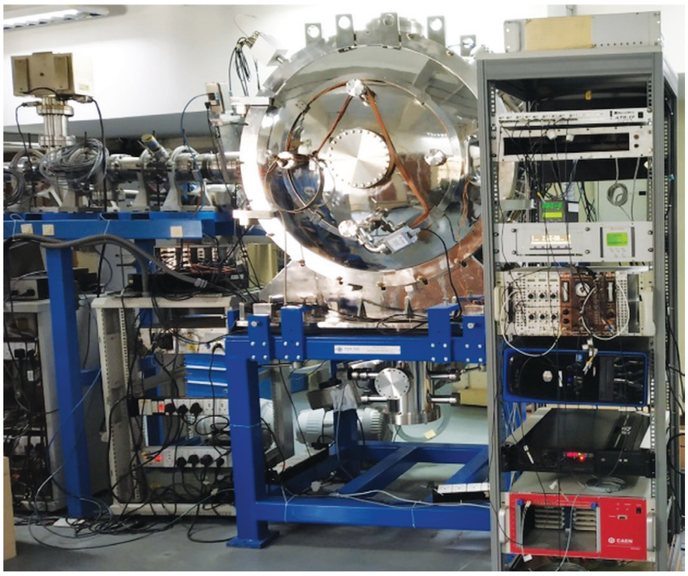


Figure 1: Photograph of the newly developed experimental setup

(2) To study the electron capture by the target gas molecules, a new position sensitive dual-micro channel plate detector has been installed at the exit port of the chamber. The projectile ions interact with an effusive jet of the target gas. One or more electrons from the projectile ion may get captured by a target molecule. An electrostatic energy analyzer is used to deflect these projectile ions according to their energies and charge states after interacting with the target. These are termed as post collision projectile ions. Due to the electron capture process, a number of charge states of the projectile ions are observed at the detector.

A test result for 450 keV Ar^{9+} ion beam interacting with neutral Ar molecules is shown in Figure 2. The different charge states of the Ar^{9+} projectile after a few electrons are captured by the target are clearly visible in this figure.

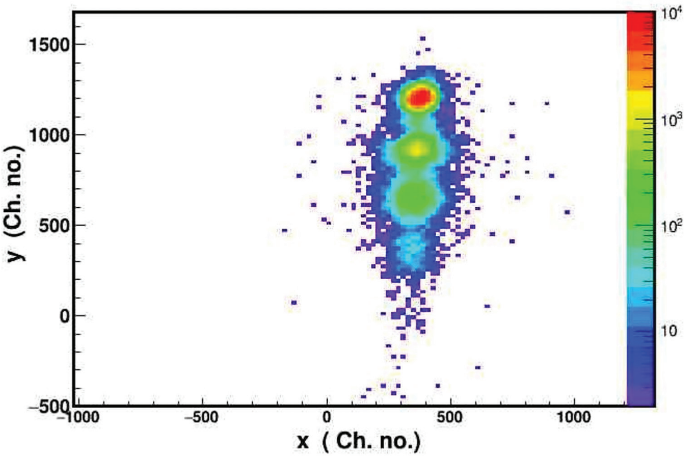


Figure 2: Position spectrum of the post collision ions in 450 keV Ar^{9+} interactions with Ar

(3) The experiments on the interaction of 50 and 200 kV/q Ar^{9+} ions with the Acetylene (C_2H_2) gas targets are performed using the ion momentum mapping spectrometer installed in the above mentioned chamber. The analysis of the acquired data is underway. A typical time of flight spectrum and a double ion coincidence spectrum of the recoil ions generated from C_2H_2 in these collisions in capture and/or ionization events are shown as below:

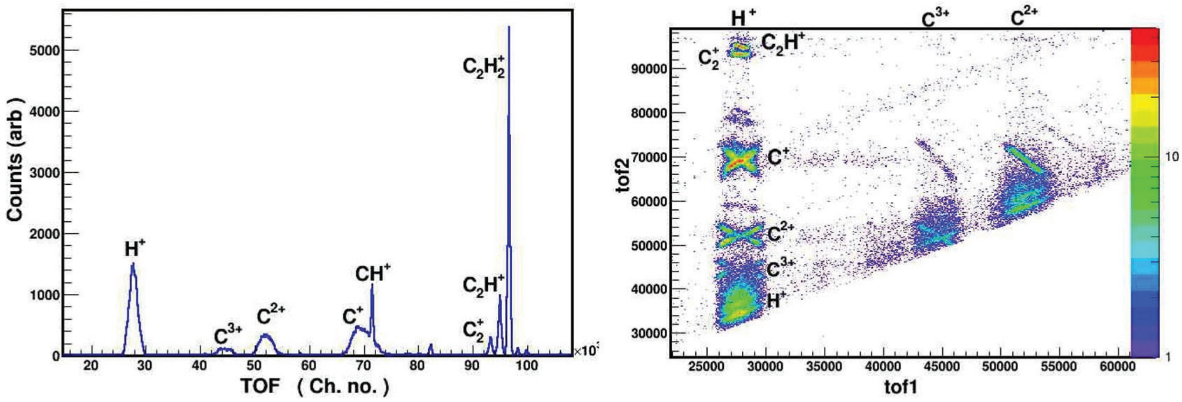


Figure 3: Time of flight spectrum (left) and double ion coincidence spectrum (right) generated in 1.8 MeV Ar^{9+} impact on C_2H_2