Upgradation of the 3 MV Van de Graaff Accelerator facility of Bangladesh Atomic Energy Commission

A. K. M. Fazlul Hoque[a], Swapan K. Biswas[a], Md. Asad Shariff[a], Md. Joynal Abedin[a], Kazi Md. Amjad Hussain[a],Md. Abu Shameem[a] ,Faizul Mohammad Kamal[b]
[a]Accelerator Facilities Division, [b]Non-destructive Testing Division , Atomic Energy center, P. O. Box 164, Ramna, Dhaka 1000, Bangladesh

Abstract

The 3 MV Van de Graaff accelerator and its associated facility of Atomic Energy Centre Dhaka (AECD) has been upgraded after a long time under the financial and technical support from IAEA. A new special, large chamber was designed with computer control sample movement facility and has been constructed at Ruder Boscovic Institute, Jagreb, Croatia and later successfully installed at the AECD. The aim is to perform simultaneous ion beam analysis techniques such as Proton Induced X-ray Emission (PIXE), Proton Induced Gamma Emission (PIGE), Rutherford Backscattering Spectrometry (RBS) and Nuclear Reaction Analysis (NRA), etc. with a millimeter size beam. A number of associated equipments such as new detectors, data acquisition system, data analysis software; vacuum systems, etc were procured and installed. Different necessary attachments were designed and fabricated at AECD workshop to install the new equipments. A good control of the size of the beam spot and the current has been achieved with a combination of slits, ion source focusing and quadrupole magnets.

Introduction

The Accelerator Facilities Division (AFD) has a 3 MV Van de Graaff Accelerator, which has been installed in 1964. The division is a nuclear technique based laboratory is responsible for providing operation of the accelerator and giving the support of maintenance of its associated auxiliary systems. The associated auxiliary system includes the high vacuum pumping systems, the cooling water supply systems, insulating gas drying system, etc. The division is involve (a) to develop ion beam experimental facilities of the accelerator (b) to utilize the accelerator ion beam for research and development works in the field of health, environment, agriculture, industry, etc. (c) to provide accelerator beam time to other users for research and service purposes and (c) to provide analytical services using ion beam analytical (IBA) techniques.

During the last 45 years the scientists have been utilizing the Van de Graaff Accelerator extensively for performing research as well as service works for quantitative elemental analysis of environmental, biological, agricultural and industrial samples using various IBA techniques Proton Induced X-ray Emission (PIXE), Proton Induced Gamma Emission (PIGE), Rutherford Backscattering Spectrometry (RBS) and Nuclear Reaction Analysis (NRA) [1-5].

In collaboration with the Universities research works utilizing the ion beam facilities of the 3 MV Van de Graaff Accelerator are being carried out for academic degrees leading to Ph.D., M. Phil., and M.Sc. in the field of Nuclear Physics, Environmental Sciences, Analytical Chemistry, etc.

In recent years the accelerator has not been performing properly. The high voltage was unstable with significant number of sparking including tube sparking and the beam was highly unstable. The operator has to work hard to keep the beam on target. Due to lack of funding and scarcity of the spare parts the idea of regular repair and maintenance has been discarded and opted for maintenance only after total failure. Initially this may have been fruitful for the users to get more beam hours but at the cost of beam quality. Due to wear and tear many sub-system of the accelerator and the terminal electronics were failing/burning frequently. For repair and maintenance of those equipments the down time of the accelerator was increasing day by day, hampering the research work. Thus a rigorous repair and maintenance and upgradation work plan of the facility has been undertaken. Initially with internal funding the following upgradation were done. The old magnet power supply (Regatron) driven by corona stabilizer unit using the slit signal to stabilize the beam was not working properly. Frequent failure of the electron tubes used in the circuit was another problem since those tubes were out of market. To replace the unit a new Danfysik magnet power supply has been procured and installed. The old NMR to measure the magnetic flux was out of order for few years thus a new hall probe tesla meter has been procured and installed to measure the magnetic field of the analyzing magnet. New Turbo pumps were bought and installed in place of diffusion pumps. Cooling water supply piping and the water were changed to improve the resistivity of the slits to improve the beam stability. Later an amplifier has been designed, constructed and installed close to the slit to amplify the slit signal to increase the sensitivity of the stabilizer unit, which was originally designed for high current and at present low currents are mostly used in IBA techniques. The filters in the gas-drying unit has been cleaned and replenished with new silica bids.

For more upgradation work and financial assistance an IAEA Technical Cooperation (TC) project entitled "Rehabilitation and Refurbishment of the Van de Graaff Accelerator" has been sought and granted. Under the scope of the TC project a team of expert visited the facility and a detailed work plane has been formulated to upgrade the facility. Accordingly the following works were carried out successfully.

Renovation of the Van de Graaff Accelerator

In recent years different terminal electronics of the Van de Graaff Accelerator has been failed/burned more frequently than before. Now under the TC project a rigorous maintenance work has been undertaken. A list of spares has been made and eventually most of them were procured under the TC project. After some discussion the deflection bias supply in the focusing assembly has been grounded since the pulsing mode beam is no longer needed. The isolation and tube focus transformer has been identified faulty and replaced with new ones. The length and positioning of the control rods has been redefined to prevent frequent failure of the magnetic contact relay and variacs. A number of high watt resistors and capacitors in the terminal electronics have been replaced with new ones. The thick wire, which supplies minus 40 kV tube focus to the first three segments of the accelerator tube was bent and marks of sparking were found from this point to the nearest ground, which may be one of the main reasons of beam instability. The wire has been straighten and removed from the vicinity of the ground. A new palladium leak assembly has been installed and one thermo mechanical leak has been repaired thus now two thermo mechanical and one palladium leak is operational. After careful checking dark gray marks of spark paths between some accelerator tube segments were found and those segments were shortened. All the column resistors were removed and measured with mega ohmmeter and the faulty resistors were replaced with new ones. The set of corona needles has been found eroded and replaced with new one. The ion source bottle was found darkened and has been replaced with a new one. The tuning of the new ion source has been done.

Upgradation of the beam lines and Ion Beam Analysis (IBA) facility

Before this upgradation, there were two beam lines at the end of the Van de Graaff accelerator of the division. The beam line to the right with respect to the ion beam direction is extensively used for PIXE and PIGE analysis and the left beam line is used for RBS analysis.

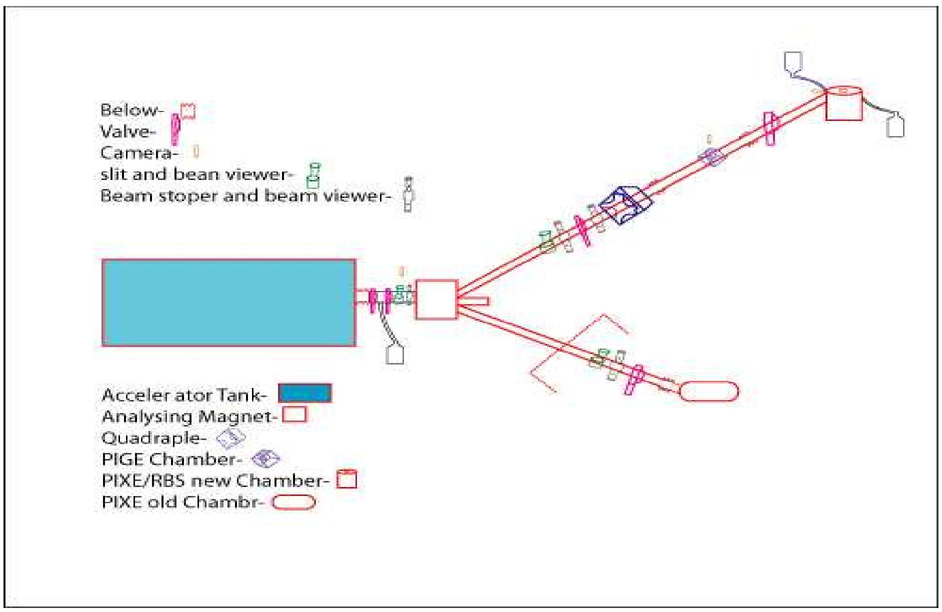

Figure1. Present layout of the Accelerator Facilities Division

In figure 1 a schematic overview of the facility has been shown. These chambers are dedicated chamber that is they are made to perform only one technique and thus not suitable for performing other experiments. These beam lines and their associated facilities/equipment is very old, manually controlled and difficult to use. Thus to achieve better control over the beam and to perform automatic and high quality research work it was necessary to modernize the facilities. The modern idea [6,7] is to have the possibilities to perform different ion beam techniques simultaneously to extract maximum information from the target in a single experiment. Thus a new experimental chamber has been designed and constructed at Ruder Boscovic Institute, Jagreb, Croatia and later successfully installed at the left beam line of the accelerator facility division (AFD) of AECD. In the designing of the new IBA scattering chamber, necessary space and ports were incorporated to accommodate the most useful IBA techniques, such as PIXE, PIGE, NRA, RBS and ERDA [8,9]. The chamber is a cylindrical shape with diameter of 130 mm and of height 120 mm. The chamber has 19 different ports, one CCTV camera, light inside the chamber, electron suppressor, faraday cup, etc. and a computer controlled sample wheel, which is electrically isolated from the chamber.

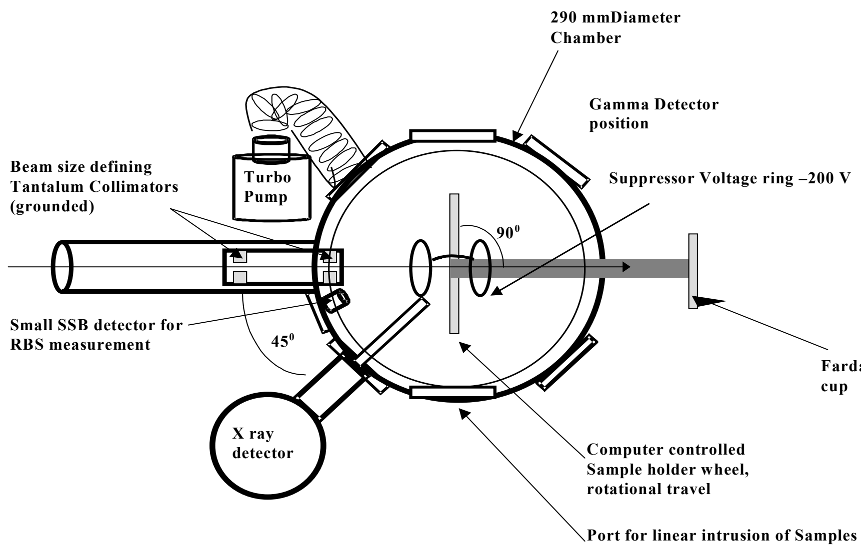

Figure 2. An overview of the new chamber and the PIXE set-up at the left beam line.

In figure 2 a schematic overview of the chamber and associated facility has been shown. More details of the chamber and calibration of the set-up for different IBA techniques will be described elsewhere. The length of the left beam line has also been increased to accommodate a new beam viewer with video camera with a view to facilitate the focusing the ion beam on the beam viewer with the help of the existing quadrupole magnets to get a large beam at the chamber.

Vacuum

A large turbo pump positioned just before the analysing magnet evacuates the accelerator tube and rest of the beam line. Two more turbo pumps located beside each of the chamber at the end of each beam line provide the vacuum in the chamber and part of the beam line. Vacuum of the order of 2.0×10^{-5} mbar is regularly achieved in the chamber.

Overall control

It is very useful for the operator if he/she can view the physical size and brightness of the beam from the control panel. To achieve maximum control over the beam direction, beam viewers plus four high quality CCTV camera with a quad monitor are connected to a TV monitor in the accelerator control panel. The beam current can be measured at three beam stops positioned along the beam line and at the Faraday cup, to optimise the beam for the investigation in hand. All these parameters can be controlled from the accelerator control panel.

Beam current and beam spot size

For most of the applications a beam current in the range of 1 - 200 nA is required. The accelerator produces a beam intensity of 1-3 μA, so that the beam current needs to be substantially reduced in order that the sample is not damaged by radiation. For this purpose a manually controlled and water cooled tantalum slit, with an opening in the range of mm is used. In the left beam line the slit is followed by a quadrupole doublet, which is used to focus the beam onto a viewer at a distance of 30 cm. Hence a divergent beam is created and from this beam a homogeneous central part is cut out by a collimator package positioned just inside the chamber. To control the beam spot current on the target mainly the ion source focusing and the Q-doublet excitation current are used. Thus it is possible to have currents on the target ranging from 5 nA up to 200 nA. The quadrupole magnet power supplies were not working properly. They were repaired and two new power supplies have been bought.

Data-acquisition system

One of the essential parts of an ion beam experimental set-up is the data-acquisition system [10]. The general requirements are that it should be able to process high count rate data with low dead time, it should be able to read a number of detectors with varying count-rate in parallel, and finally to be able to store and display the data. User-friendly interface software to perform all the necessary operations with relative ease is also required. For signal processing new NIM standard modules and the ORTEC 919E -based data acquisition system with MAESTRO interface software are procured and are used for data handling.

Discussion

Under the scope of the TC project a number of other equipments such as, new detectors, detector bias supply unit, amplifiers, data acquisition system, current integrator, data analysis software, dew point meter, Helium leak detector unit, vacuum equipments, etc. are being procured and installed. In order to install the new equipments successfully different necessary attachments were designed and fabricated locally (at AECD workshop). After this upgradation work the Van de Graaff Accelerator has been operated successfully with a very stable beam to be used for research and development purposes. There was no major instrumental breakdown, especially; the electronic circuits in the terminal top plate did not fail, which is a great achievement compared to the earlier years and has proved the success of upgrading and renovation works. However, the operation of the Van de Graaff accelerator has been interrupted on many occasions due to frequent voltage fluctuation and phase failure. A new three-phase 100 kVA voltage stabilizer has been procured and installed in the facility, which solves the problem so far. During the period, most of the research effort was devoted towards the installation and characterization of the new beam line, experimental chamber and other new equipments. A lot of beam hours were spent to perform standardization and calibration experiments with the newly installed experimental set-up with a view to enhance the analytical quality of the laboratory for analyzing different types of samples.

Applications of the new beam line

The new beam line and ion beam analysis facility will be extensively used for routine PIXE analysis of the following samples:

Aerosol samples collected on polystyrene filter material.
Biological samples like human blood, milk, hair, nail, etc.
Fish, shrimps, etc.
Environmental samples like water residue, lake sediment, soil, etc.
Plant samples like chewing sticks.
Material analysis with PIXE and RBS experiments for solar cell material, thin films, etc.

Conclusion

The 3 MV Van de Graaff accelerator and its associated facility of Atomic Energy Centre Dhaka (AECD) has been upgraded as part of the development process of the AFD facility, as demand for better analytical results are growing in many fields of research. The support from the IAEA for this work is greatly acknowledged.

References

[1] Indoor air pollution from particulate matter emissions in different households in rural areas of Bangladesh. Bilkis A. Begum, Samir K.Paul, M.Dildar Hossain, Swapan K. Biswas, Philip K.Hopke. Building and Environment 44(2009)898-903

[2] Assessment of trends and present ambient concentrations of PM2.2 and PM10 in Dhaka, Bangladesh. Bilkis A. Begum, Swapan K.Biswas, Philip K.Hopke. Air Quality Atoms Health, Accepted 20 October 2008.

[3] Temporal variation and spatial distribution of ambient PM2.2 and PM10 concentrations in Dhaka, Bangladesh. Bilkis A. Begum, Swapan K.Biswas, Philip K.Hopke. Science of the Total Environment 358(2006)36-45

[4] Study of the Composition of Vacuum Deposited Thin films of Cu-In-Se using PIXE and their properties. M. Khaliquzzaman, S.K. Biswas, A.H. Khan, Feroz Hassan, M.A. Subhan and L. Kadir. Nucl. Instr. Meth. Phys. Res. B114 (1996)332-336.

[5] A.K.M. Fazlul Hoque and M. Khaliquzzaman,"Characteristics of PIGE Setup with the Dhaka Van de Graaff and its use for Light Element Analysis in Environmental Related Samples", Internal Report, AECD/AFS-CH/12-52, May, 2000.

[6] Calibration of a new chamber using GUPIX software package for PIXE analysis, Asad Shariff, Karin Bulow, Mikael Elfman, Per Kristiansson, Klas Malmqvist, Jan Pallon, Nucl. Instr. Meth. B 189 (2002) 131-137.

[7] Lund Nuclear Microprobe, Sub-Micron set-up, Part III: Sample stage, optical Imaging and detector configuration in the experimental chamber. M. Elfman, J. Pallon, V. Auzelyte, P. Kristiansson, K. Malmqvist, C. Nilsson, A. Shariff, M. Wegdén, Nucl. Instr. Meth. B231 (2005) 14-20.

[8] Sven A. E. Johansson and John L. Campbell, A novel Technique for Elemental Analysis, John Wiley & Sons. 1988.

[9] Joseph R. Tesmer, Michael Nastasi, Handbook of Modern Ion Beam Material Analysis, Material Research Society, 1995.

[10] Asad Shariff, PhD Thesis, Lund university, 2004.