Development of research facilities using high current low energy 3.0 MV particle accelerator at NCAR, Bilaspur

T. Trivedi, Shiv P. Patel C.Mallik, Rakesh Kumar, P.K. Bajpai
National Centre for Accelerator based Research, Department of Pure & applied Physics,
Guru Ghasidas Vishwavidyalaya, Bilaspur-495009, INDIA
** email:bajpai.pk1@gmail.com & ttrivedi1@gmail.com*

Introduction

Low energy and high current accelerators have an important role to play in different fields such as Nuclear Physics, Material Science, Biology, Nanotechnology, Bio-medical, Agriculture, Food processing etc. However, advances in accelerator technology coupled with state-of-the-art detection systems on one side have provided scope of studying neutron induced reaction cross-sections, neutron activation analysis (NAA), neutron scattering and low energy nuclear astrophysics. On the other side, the ion beam nuclear techniques such as particle induced X-ray emission (PIXE), Rutherford Backscattering (RBS) have offers tools for the elemental analysis which has wide applications in various areas of Science and Technology [1, 2]. In the present contribution, we shall mainly focus on features of low energy high current Pelletron accelerator along with the development of research facilities like PIXE, RBS, channeling and future prospects of machine for neutron generation.

Present Status of Accelerator Facility

The facility has been established at GGV, Bilaspur for providing accelerator based research tools in interdisciplinary research areas using ion beams. The 3.0 MV Pelletron accelerator (9SDH, NEC) with high current TORVIS and SNICS-II ion sources has unique features for this purpose. The TORVIS source provides negative ions of hydrogen and helium whereas SNICS-II is used for heavy elements producing negative ions. The Pelletron has been successfully commissioned in November 2014 and desired level of terminal voltage and vacuum in the accelerator tank was achieved after conditioning over a period of time. Finally, 3.0 MV terminal voltage is achieved with chain currents ≈120 μA and an applied charging voltage of 13 kV. The vacuum without beam acceleration was better than 10^{-7} torr on both sides of the Pelletron tank.

Table 1: Beam parameters achieved during test run at terminal potential 3.0 MV

Ion Source	Ion species	Beam current at Faraday cup L1/L2 (μA)	Ion Energy in MeV
SNICS-II	Au^{2+}	0.958	9.00
	Au^{3+}	11.7	12.00
	B^{2+}	3.17	9.00
	Ni^{2+}	13.0	9.00
	Ni^{3+}	19.9	12.00
	Ni^{4+}	13.8	15.00
	Ni^{5+}	7.6	18.00
	Ni^{10+}	1.0	33.00
TORVIS	He^{2+}	0.658 (FCL1)	9.00
	He^{2+}	12.3 (FCL2)	9.00
	H^{+}	50.0	6.00

The first beam demonstration was done with a proton beam accelerated with terminal potential of 0.965 MV on the Al target in Ion Beam analysis (IBA) chamber, the current at the Faraday cup (FC) just before the chamber was 0.5 eμA. Thereafter, we have successfully transported H^{+}, He^{2+}, and various charge species of C, B, Ni and Au ions up to the end station in both beam lines. The maximum ion currents and ion energy at 3 MV terminal potential achieved so far are summarized in Table 1. Using the beam profile monitors (BPMs) at several places in the beam lines, the beam profiles have been monitored and parameters of focusing elements (beam diagnostic devices and magnets) were optimized. Accelerator terminal voltage at GVM was calibrated with oxygen on aluminum well known resonance reaction using RBS technique.

Ion beam analysis Facilities

The facility includes two dedicated beam lines, one for ion beam analysis (IBA) and other for ion implantation/ irradiation corresponding to switching magnet at +20 and -10 degree. The with ME/Z^2 of bending magnet is 310 amu-MeV and that of analyzing magnet 78 amu-MeV. The beam line at 20 degree port is dedicated for Ion Beam Analysis consisting of facilities for Rutherford Backscattering (RBS), Particle Induced X-ray Emission (PIXE) and double slit for channeling. There is a separate port for RGA mounting.

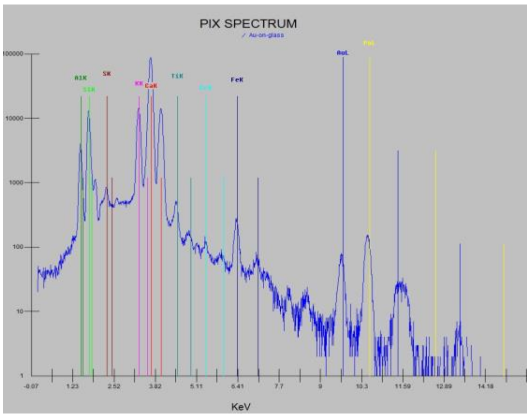

Fig. 1 A PIXE spectrum of Au thin film on Glass substrate

A number of test experiments were performed to demonstrate the capabilities of the ion beam analysis facilities commissioned in the beam hall. Particle induced X-ray emission experiments have been carried with proton beam on several targets like ZnO, gold on glass and various coins and some other samples. For X-ray analysis a Silicon Strip Detector (SDD) is mounted at a backward angle relative to the incident beam to reduce the possibility of scattered protons entering the detector. The PIXE data is collected using RC43 software package. A typical PIXE spectrum of Au thin film on Glass substrate using 1 MeV proton beam is shown in Fig.1. In order to find depth profile of individual elements, Rutherford Backscattering (RBS) experiments were performed using Helium beam. The scattered He particles from the target are analyzed by a Silicon Charge particle detector (50 mm active area with energy resolution of 11 keV and 300 micron depletion) positioned at a backscattered angle with respect to the incident ion beam. The facility is fully operational and available to users for experiments.

Future Prospects

The main feature of this accelerator from neutron activation research point of view is the high current TORVIS ion source which provides high proton beam current (max. 50 microamperes @ 6 MeV that can be achieved at the target). In order to utilize this facility, the zero degree beam line will be extended to new beam hall for neutron production and a high neutron flux ($4.5x10^9$ neutrons/cm^2/sec) can be achieved in the second phase already approved by DAE-BRNS. The generated neutron flux will provide unique opportunity for neutron-induced cross sections measurements especially in low energy region where very limited information are available. Neutron Activation Analysis (NAA) along with several other applications in neutron based research is the focus in future. This development would fill up the wide gap existing in the neutron cross section data, important for the design and development of new generation of reactors. The facility is aimed to initiate neutron related activities at NCAR

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References

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