TEST RESULT WITH FOIL STRIPPER ASSEMBLIES INSTALLED AFTER 15 UD PELLETRON ACCELERATOR

S. Ojha[#], S. Chopra, R. Joshi, S. Gargari, K. Devarani, M. Sota, P. Kumar, V. Patel, R. Sharma, D. Kabiraj, S. R. Abhilash, P. Barua, A. Kothari, J. Prasad, R. Kumar, M.P. Singh, N. Panwar, S. M. Nishal, S. Kumar, P. Singh, D. Kanjilal, IUAC, New Delhi, India.

Abstract

Two foil stripper assemblies with provision for loading 50 foils of 5/8 – inch diameter has been installed after 15 UD Pelletron accelerator at IUAC. Assembly number one, installed before analyser magnet, will be utilized for providing ion beams with high charge state to the linear accelerator to attain higher energies. Second assembly, which is installed after analyser magnet will be used for isobar separation for AMS measurements, charge state dependent studies and low flux irradiation requirements. Initial beam test of these foil stripper assemblies has been performed with carbon foils installed on them. Equilibrium charge state distribution measurements of silicon, iron, nickel, bromine, iodine and cesium ion when stripped with carbon foil after analyser magnet have been carried out in the energy range of 70 – 100 MeV. Observation of non – Gaussian distribution in these measurements is due to electronic shell closure.

INTRODUCTION

15 UD Pelletron accelerator at IUAC [1-2] is equipped with a foil stripper and a gas stripper at high voltage terminal. Besides these, accelerator is equipped with foil stripper assembly at High Energy Dead Section (HEDS) of Pelletron accelerator. Incoming negative ion passing through the strippers at terminal loose electrons and becomes positively charged. The foil stripper at HEDS increases the positive charge state of ion by removing more electrons, which helps in delivering ion beams at higher energies. Typical thickness of carbon foils loaded in the foil stripper assembly in the terminal is around 4 microgram per square centimetre (4µg/cm^2). A 50 position - foil stripper assembly is installed after analyser magnet. Energetic ion beam passing through this foil will be excited to higher charge states but there will be no increase in energy.

Investigation of charge state distribution of various ions with carbon foil stripper has been widely reported. The empirical formula of charge state distribution width and mean charge state on Z (target atomic number) by Nickolaev and Dmitriv [3] provides good estimate of distribution function. But strong non – Gaussain distribution is generally observed due to electronic shell effect. In this paper, besides testing installed assembly, distribution width and mean charge state of Si, Fe, Ni, Br, I and CS and their comparison with empirical formula of Nickolaev and Dmitriv is reported

[#]sunil.mumbaikar@gmail.com

EXPERIMENTAL PROCEDURE

Si, Fe, Ni, Br, I and Cs beam of 2 mm diameter from Pelletron accelerator was stripped through carbon foil stripper of 10µg/cm^2 thickness. Charge state after stripping was analysed by doubly focusing magnet, bending the beam by 45 degrees in one of the experimental beam lines. This was done using computer program scanning the magnetic field from high value to low value. To minimise error due to manual tuning and other steering effects, all other optic elements were kept off. Each charge states were measured using electron suppressed Faraday cup in the beam line.

RESULT AND DISCUSIION

Normalised Charge state distribution of Fe, Ni, Br, I and Cs is plotted in Fig.1. It was observed that charge state as high as 19 to 20 can be delivered in case of 75 MeV Fe and Ni. In case of I and Cs at the energy range of 80 MeV, 28+ charge state can be provided to the users. Wide range of charge states with fixed energy is available in all cases which will be beneficial to the atomic physics and material science users.

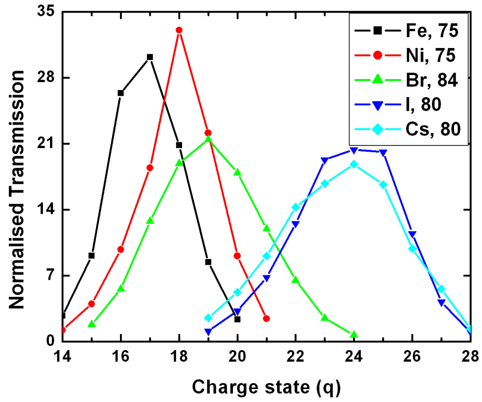

Fig. 1 Charge State distribution of Fe, Ni, Br, I and Cs.

Effect of electronic shell on the charge state distribution[4] was observed in the case of Fe, Ni and Cs. Fig.2 is plot of natural log of ratio of F(q+1) to F(q) for Ni ions. For gaussian distribution this should be straight line. Any deviation from straight line suggests deviation in the Gaussian distribution.

It is observed that deviation occurs at 18+ where transition from *M shell* to *L shell* takes place in case of

Ni. Such effects were also observed in the case of Fe and Cs. In the case of Cs it was observed for transition taking place from *N shell* to *M shell*.

It is observed that deviation occurs at 18+ where transition from *M shell* to *L shell* takes place in case of Ni. Such effects were also observed in the case of Fe and Cs. In the case of Cs it was observed for transition taking place from *N shell* to *M shell*.

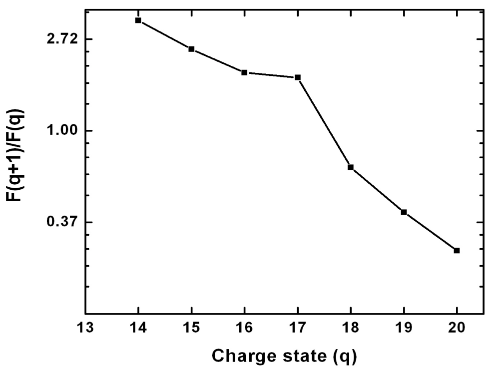

Fig. 2 Charge fraction rations F(q+1)/ F(q) of 75 MeV Fe, stripped through carbon stripper.

Centroid of the distribution which is measure of mean charge state, and width of the distribution d are defined as

$$\langle q \rangle = \sum_q qF(q)$$

$$d = \left\{ \sum_q \left(q - \langle q \rangle \right)^2 F(q) \right\}^{1/2}$$

where F(q) is charge state fraction for charge q.

Experimental data is compared with the empirical formulas for mean charge and distribution width by Nikolaev and Dmitriev

$$\frac{\langle \mathrm{q} \rangle}{\mathrm{z}} = \left(1 + X^{-1/.6}\right)^{-.6}$$

$$d = 0.5 Z^{.5} \left(1 + X^{-1/.6}\right)^{-.8} X^{-1/1.2}$$

where X is reduced velocity defined by

$$X = \frac{v}{3.6x10^8 Z^{0.45}} \left(1 + X^{-1/.6}\right)^{-.6}$$

v is velocity of ion in cm/sec.

Table 1 lists the observed and calculated mean charge state and distribution width for Si, Fe, Ni, Br, I and Cs. They are found to be in good agreement.

Table 1: Observed and measured mean charge state <q> and distribution width 'd'

Ion & Energy	**<q> meas.**	**<q> calc.**	**d meas.**	**d calc.**
Si, 80 MeV	11.52	11.84	0.87	0.85
Fe, 75 MeV	16.92	17.36	1.28	1.46
Ni, 75 MeV	17.89	18.22	1.41	1.53
Br, 84 MeV	19.06	20.41	1.81	1.74
I, 84 MeV	23.54	22.81	1.79	2.07
Cs, 80 MeV	22.97	23.81	2.1	2.05

CONCLUSION AND FUTURE SCOPE OF WORK

Foil stripper assembly with provision for loading 50 foils of 5/8 " diameter was installed at the image point of analyser magnet of 15 UD Pelletron accelerator at IUAC. Initial beam tests were performed to analyse the performance of the assembly. It was observed that higher charge states were available which was not possible to deliver from Pelletron accelerator. Also wide range of charge states was available for a given energy. Effect of electronic shell on charge state distribution was observed in case of Fe, Ni and Cs. Measured mean charge states and distribution widths were compared with calculated values.

The foil assembly can also be utilised for measuring charge state dependent energy loss for incident beam. It is also proposed to study effect of thickness on the mean charge state of ion beam delivered from Pelletron accelerator. Isobar separation for AMS measurements has to be carried out.

ACKNOWLEDGEMENT

Authors wish to thank Director, IUAC for his continuous encouragement for accelerator based research.

REFERENCES

[1] G.K. Mehta, A.P. Patro, NIM A 268 (1988) 334.
[2] D. Kanjilal et. al., NIM A 328 (1993) 97.
[3] V.S. Nikolaev and I.S. Dmitriev, Phys. Lett. 28A (1968) 277
[4] C. D. Moak et. al., PRL 18, 41 (1967)