Introduction

An ion accelerator is an indispensable tool of scientific and industrial research. Apart from giant and high energy charged particle accelerators, there is a big need of low energy ion accelerators for scientific research purposes, for e.g., low energy ion beam is required for (1) material modification and characterization [1], (2) the study of low energy particle induced nuclear reactions in nuclear astrophysics, (3) study of after-effects (mutation) of ion beam irradiation on crops and vegetables [2] etc.

Since the early days of development of an ion accelerator, it has always remained important to produce a focused ion beam with a minimum of undesired charged particles and molecular ions. To get such kind of ion beam, design and development of beam optics elements become so important. In this paper we will discuss the design of the following beam optics elements – (1) Electric Quadrupole Lens (2) Wien Velocity Filter which will be the part of 50 keV table-top ion accelerator being developed at Indian Institute of Technology, Roorkee with the technical support of Inter University Accelerator Centre, New Delhi.

Electric Quadrupole Lens

The proposed ion source shall deliver 100s of μA particle beams in the energy range between 10 - 50 keV. Therefore, the beam, after coming out of the extractor geometry, shall be highly space-charge dominated and will require adequate focusing. We shall use electrostatic field based focusing device since they are best suited for low energy, non-relativistic particles. The electrostatic beam rigidity for non-relativistic charged particles is given by:

\[ E[V/m], \rho[m] = 2 \frac{E_{\text{kin}}[eV]}{A Z} \]

Due to the mass independence of the electrostatic rigidity, even heavy particles can be steered. Usually, a quadrupole doublet lens is used for parallel to point focusing, however, we need a relatively larger focal length to accommodate Wien Velocity Filter, another important ion optics element, discussed in the next section. Therefore, for a symmetric point to point focusing, an electric quadrupole triplet lens (EQT) is preferred since they allow to focus the charged particles down over long distances.

For example, for a 50 keV proton beam the electrostatic rigidity is 10^5 Volt. In our design, the total length \( L \) of EQT is 400 mm and the aperture size \( a \) is 60 mm. The focal length \( f \) of an EQT is related to electrostatic rigidity \( E \rho \) by:

\[ f = \frac{E_0}{a} \frac{1}{E \rho} \sin \left( L \frac{E_0}{a} \frac{1}{E \rho} \right) \]

For a focal length of approximately 1 m, the electric field \( E_0 \) is around 22 kV/m. The detailed design of EQT is being worked out.

Wien Velocity Filter

There are some sophisticated and sensitive experiments in nuclear astrophysics in which small amount of undesired particles (particles of different masses and charge state) may alter the results tremendously. To overcome this problem, Wien Velocity Filter (WVF) will be used in 50 keV table-top ion accelerator, being developed at IIT, Roorkee. WVF has electrostatic and magnetostatic fields in transverse directions with respect to the direction in which ion beam is
Figure 1: Schematic diagram of WVF travelling. It is a mass-separator device through which the ion beam will be transported to the target. A suitable choice of electrostatic field $E$ and magnetostatic field $B$ ($\frac{E}{B} = v$), sets up a deflecting force that will allow the particle with suitable velocity ($v$) pass through it and deflect the undesired particles. The main problem in the design of magnetic and electric plates of WVF is the large amount of fringe fields. To overcome this problem we have simulated the design of electric plates using Poisson Superfish [3] field solver. In the simulation we got the uniform electric field strength between the plates and reduced amount of the fringe field up to approximately 30 V/cm. Left plate is at +5 kV and right plate is at -5 kV with the thickness of 2 mm. To reduce the fringe field, stainless steel plates are fitted in a material with a high dielectric constant ($\varepsilon_r$) as shown in Figure-2.

Figure 2: E-field plot between the plates

Conclusion
The design of EQT is being worked out with space charge considerations. The WVF is under fabrication.

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References