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Computer investigation of ion beam optics for a Freeman type ion source system

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ABSTRACT

The present work investigates the computer analysis of the ion beam properties produced by a Freeman type system. The extraction for such system is composed of four electrodes that permit to keep a fixed output energy by means of two accelerating gaps and one decelerating gap. The latter allows reducing the beam divergence angle. The combination of the acceleration/deceleration sections provides to keep a low beam emittance at the source outlet. The simulation of single charged argon ion trajectories for a plasma concave of curvature 4 mm was first studied with and without space charge effect using acceleration/deceleration extraction system with the aid of the SIMION computer program. The voltage applied to the accelerating electrode was optimized to accomplish the suitable ion trajectories without hitting the extraction electrode. Then, two additional studies were performed: the influence of the acceleration voltage and extraction voltage on the beam emittance and beam diameter; and the effect of the extraction gap width (distance between the plasma emission surface and the acceleration electrode) on the shape of the ion beam envelope and the position of the ion beam waist. Last, the influence of the space charge on the ion beam envelope was also investigated.

1. Introduction

Ion sources [1] with high gas efficiency and single to high charge state ion beams with high beam quality are needed in various applications, ranging from radioactive ion beam production to high energy ion implanters. Ion sources are devices for producing and delivering ion beams that may be directly used from the source or after acceleration by a simple or complex accelerator structure [2–6]. For ion sources, some of the residual gas particles that are present within the beam line will be ionized by the beam. Consequently, a sufficient number of secondary electrons can be generated and, under the influence of the extraction field, be accelerated back into the source. One of the criteria of an efficient ion source is to prevent or reduce such process. Recently, a heavy ion injector was installed at the Accelerators and Ion Sources Department, Nuclear Research Center, Atomic Energy Authority (A.E.A), Egypt [7]. The system is intended for use I isotope separators and ion implantation, as well as for research the physics and technology of ion sources. It is complete with power supply, control, vacuum and cooling system. This source [8] was supplied by Efremov Research Institute of Electro physical Apparatus, Saint Petersburg, Russia. The extracted ion beams are particularly quiescent and stable and different elements such as Ar, Bi, Sb, have been used before [7,9]. In the source, the ions are generated through crossed electric and magnetic fields discharge plasmas. The discharge is formed between the thermo emission core cathode and cylindrical anode surrounding it. The electrons emitted by the hot cathode have high ionization efficiency. The ions are extracted from the discharge region through an emission slit in the anode.

The system uses an acceleration/deceleration scheme to avoid compensating electrons being accelerated back into the source, thus destroying its rear side and leaving the ion beam uncompensated. The main beam characteristics of this Freeman type ion source system was investigated with and without space charge using singly charged argon ions with the aid of the SIMION computer program version 7 [10].

2. Construction of the ion source

Ions of various elements are generated in this version of a Freeman type ion source [7] and accelerated in a four electrode acceleration/deceleration system to obtain energies of up to 50 keV. The ion source and the accelerating system are constructed as a single unit mounted around the vacuum chamber of the system. A movable Faraday cup is used to measure the beam current at the aperture outlet.

A schematic diagram of this ion source system is shown in Fig. 1. It consists of a stainless steel cylindrical anode (10 mm radius, 28 mm long and 5 mm thick) and an aluminum disk cathode (10 mm radius and 3.5 mm away from the anode). The Faraday cup is located 30 mm from the aluminum cathode, and the output ion beam current extracted from a 3 mm diameter exit aperture placed

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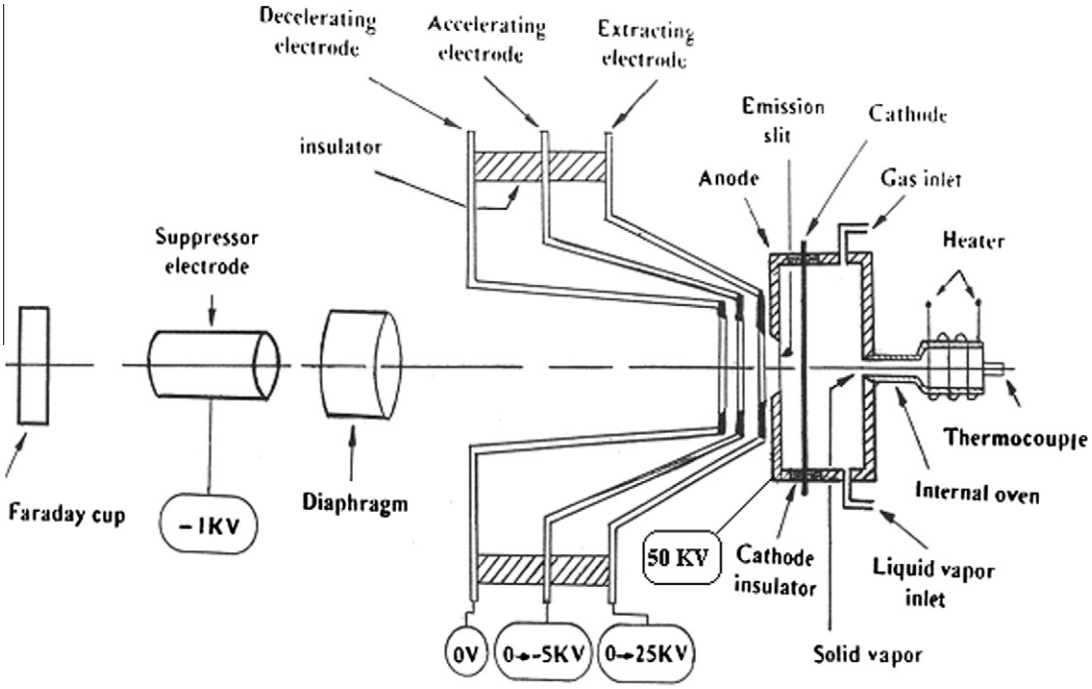

Fig. 1. Schematic of the Freeman type ion source.

at the center of the cathode. The gas is injected from the top into a Perspex container through a fixed hose.

3. Simulation process

SIMION 3 D Version 7.0 and its applications [11,12] is a software package primarily used to calculate electric fields and the trajectories of charged particles in those fields for a given configuration of the electrodes (voltage, materials and ion particles, charge state, type, etc.). This program provides extensive supporting functionality in geometry definition, user programming, data recording, and visualization. In general, the fundamental steps for simulating the properties of a model extraction system are to define the physical and electrical boundaries of the electrodes. In SIMION, the user provides the properties of the ions that make up the beam, defines the type of the data output to be recorded. The code then accelerates the ions within these conditions and simulates the trajectories through the extraction system. Each electrode of the four extraction system is separately designed using a potential array. Such a potential array is a

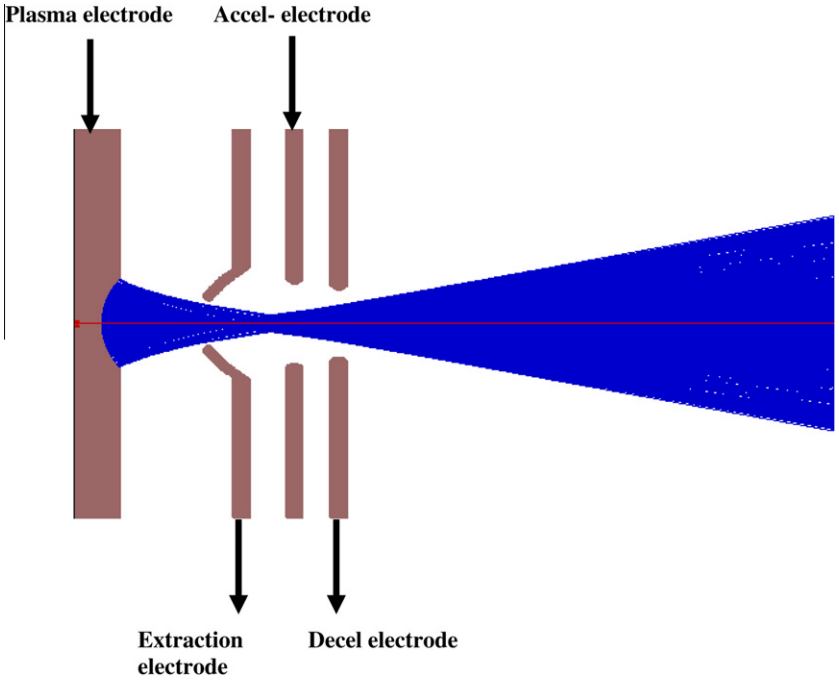

Fig. 2. The acceleration–deceleration extraction system for Freeman type ion source.