DESIGN AND FABRICATION OF PROTOTYPE 3-ELECTRODE H^- ION EXTRACTION SYSTEM FOR ION SOURCE

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Abstract

This paper reports on the 3-electrode extraction system of a first stage prototype H^- ion source being developed at Raja Ramanna Centre for Advanced Technology (RRCAT), Indore. The design of the source is based on multi-cusp filament based arc discharge type with advantage of operating in volume as well as surface production of H^- ions [1]. The major components of the source are plasma chamber, vacuum system, beam extraction chamber and electrode assembly. We have designed a prototype extraction system which is in-housed in the extraction chamber containing beam diagnostics and vacuum ports. The extraction system consists of plasma electrode made of molybdenum (floated at -10 kV), extraction electrode (-5 kV) and ground electrode, both made of oxygen free high conductivity (OFHC) copper. The high voltage insulation between the electrodes is provided by PTFE spacers. The electron steering dipole magnets are fixed at the extraction electrode to steer-out the electrons and dump them on copper dump. The design and fabrication aspects of the extraction system are presented.

INTRODUCTION

The 3-electrode extraction system has been successfully used at KEK/J-PARC, Japan for their H^- ion source as an injector for the linac[2]. Since our ion source parameters are similar to J-PARC, therefore we have designed the 3-electrode prototype extraction system comprising of cylindrical (Φ350 mm x L500 mm) extraction chamber kept at ground potential. The plasma chamber connected at the left side of extraction chamber is floated at -10 kV. In plasma chamber hydrogen gas flow can be varied between 5-20 sccm through piezo-electric gas valve. The hydrogen gas purged into plasma chamber is evacuated through an orifice in plasma electrode using a TMP of 1850 lps. The main parameters of the prototype H^- ion source are given in table 1.

Table 1: Prototype H^- Ion Source Parameters

Parameters	**Values**
Beam Energy	10 keV
Beam Current	≤ 1 mA
Pulse Width	100-500 μs
Pulse Repetition Rate	1-25 Hz
Duty Factor	≤ 1.25%
Emittance (rms norm.)	≤ 0.2 π mm mrad

Provisions for emittance measurement in X and Y planes have been made. The extraction chamber has various ports to deploy emittance monitor, Faraday cup, TMP and vacuum gauge. The extraction chamber is supported upon by two saddle supports on a stand-alone structure made of S.S. 304. The saddle and stand-alone structure facilitates alignment of extraction chamber and maintains the H^- beam axis at 1250 mm from floor level. The extraction chamber diagram is shown in figure 1.

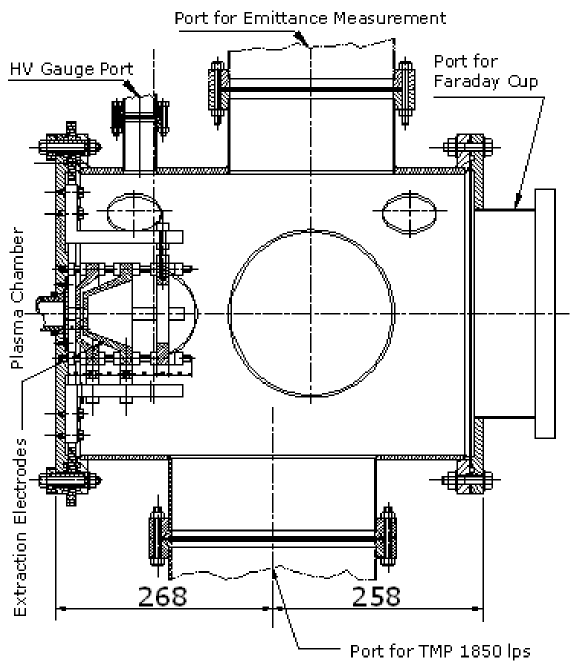

Figure 1: Extraction chamber of H^- ion source.

DESIGN ASPECTS

The primary objectives of extraction system is to achieve the desired ion current, pulse repetition rate and emittance of H^- ion beam essential for injector linac. The important parameters to meet these objectives are to improve e^-/H^- ratio in extracted H^- beam and to achieve lower emittance. Using the relation derived by Allison et al. for emittance as a function of ion temperature -

$$\varepsilon_{n,rms} = 0.0653 r_o(mm)\sqrt{\frac{kT_i(eV)}{A}}$$

where r_o is the radius of the circular aperture. T_i is the H^- ion plasma temperature and $\varepsilon_{n,rms}$ is in π-mm-mrad [4] [5].

Vacuum Requirements

The estimated vacuum requirements in the plasma and extraction chambers are typically in ~ 1E-2 mbar and ~1E-4 mbar respectively. This is achieved by differential pumping. The extraction chamber is connected through a gate valve and a vibration damping bellow. Estimation of pumping speed requirement:

Total gas load on pump = flow of H_2 gas + out gassing from various sources (can be neglected).

= 13 sccm = 0.2 mbar-litre/s.

With piezoelectric valve opened for 10% duration, the average gas flow will be = 0.02 mbar-l/s.

A TMP with 1850 lps for H_2 gas with inlet flange DN250 will be able to produce –

- Vacuum level in extraction chamber of ~1E -5 mbar.
- Vacuum level in plasma chamber of ~1 E -3 mbar.

Extraction Electrodes Assembly

The 3-electrode extraction system for the first stage prototype H^- ion source has been chosen for its simplicity. The shape of the electrode geometry is optimized using nIGUN software [3]. The plasma electrode is made of molybdenum having an aperture of Φ10 mm with Pierce opening angle of 45° with respect to beam axis. The extraction and ground electrodes are made of OFHC copper having aperture of Φ10 and 12 mm respectively. Both the electrodes are presently designed for no-cooling, however, for higher energy beam extraction, water cooling provision will be made.

The electrodes are supported upon by PTFE made support cum alignment system to optimize the extracted beam. The 3-electrode extraction system is shown in figure 2.

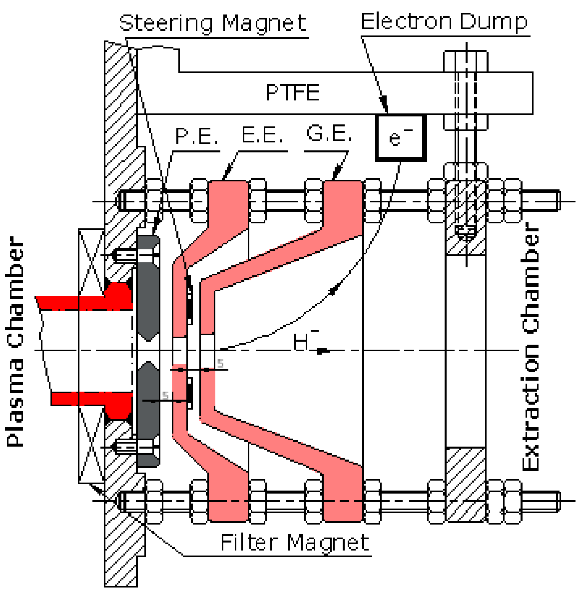

Figure 2: The 3-electrode extraction system.

Extraction Chamber

The extraction chamber has been designed as per ASME Section VIII Div.1 UG-28 and 33. The port openings have been designed as per UG-42 and 53. It has been fabricated from 14" NB S.S. 304 seamless pipe. After machining the wall thickness is 5.5 mm. The extraction chamber kept at ground potential in-houses the extraction electrodes, beam slit emittance monitor and Faraday cup. It is equiped with a high vacuum gauge and a TMP to maintain vacuum of ~1E-5 mbar. The isolation with respect to the plasma chamber (floated at -10 kV) is maintained by PTFE isolation ring and sleeves/washers. To minimize the vibration transfer from TMP to chamber, a vibration damping bellow is used along with a gate-valve in between extraction chamber and TMP.

RESULTS and FUTURE WORKS

The plasma electrode (PE), extraction electrode (EE), ground electrode (GE) and extraction chamber have been machined. Welding of required ports on extraction chamber has also been carried out. The piezoelectric valve and gate valve have been tested for their performance.

The electro-chemical polishing, helium leak testing of extraction chamber, electrical testing of PTFE support cum alignment system and design of stand–alone structure are in progress. After successful execution of above steps the extraction system will be commissioned. In this system the extraction parameters will be optimized.

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