PKU 2.45 GHz MICROWAVE DRIVEN H- ION SOURCE PERFORMANCE STUDY*

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Abstract

In a high intensity volume-produced H- ion source, H- ion production processes are great affected by electron temperature and gas pressure distribution within the discharge chamber. The H-/e ratio within an extracted H- ion beam is much depended on the electron absorption within the extraction system. At Peking University (PKU), lots of experiments were carried out for better understanding H- processes and electron dump on our 2.45 GHz microwave driven Cs-free permanent magnet volume-produced H- source. Detail will be given in this paper.

INTRODUCTION

Theoretically, H^- ion is produced in two step processes in a volume source. First, hydrogen molecules H_2 impact with fast electrons heated by microwave and vibrated to excitation state H_2*. Secondly, slow electrons interact with excited molecules H_2* and dissociate the attachment, the processes could be expressed as following:

$$e(fast) + H_2 \rightarrow H_2^* + e + h\upsilon \tag{1}$$

$$\mathrm{e(slow)} + H_2^* \rightarrow H + H^- \tag{2}$$

The energy of fast electron should above 20eV to excite the H_2 to highly rovibrationally excited molecules $H_2^*(4 \leqslant v \leqslant 9)$ [1]. Increasing microwave power could help enhance electron temperature by ionizing gas to plasma. Enhancing the possibility of electron collision with H_2 molecule and reducing H^- loss by collision with H atoms or molecules, these could be adjusted by changing the pressure within the chamber.

H^- is fragile because its electron affinity is only 0.75 eV and it is easy to be destroyed by fast electron. The filter field keeps the destructive hot electrons away from the extraction region to reduce the H^- loss in this area. Design an appropriate filter magnetic field is very important to H^- ion production.

In order to increase H^-/e ratio, the electron in the extracted beam must be dumped properly. The electron can be dumped in the collar, in the gap between the plasma electrode and ground electrode, or behind the ground electrode [2].

The 2.45 GHz microwave-driven pure volume H^- source under development could help us understand the principle of volume H^- source and enhance the performance of H^- source by optimum the structure of 2.45 GHz microwave H^- ion source. It could be a reliable and efficient H^- source for high beam power accelerator.

The significant influence of operation pressure on beam current and electron dump field on H^-/e ratio had been found during a series of experiments, the parameter of the microwave power was also adjusted, performance of PKU H^- source was improved significantly. The negative ion source is working in pulsed/CW mode without caesium (Cs). A 15 mA pure H^- ion beam had been produced at 50 keV by this developing source. The initial design of ECR ion source can be found in ref.3.

EXPERIMENT SETUP

This microwave driven H^- ion source can briefly divides into microwave matching part, source body and beam extraction system. The source body is physically separated into three sections with different function. The first section is the primary ionization chamber (ECR zone) where high temperature electrons heated by microwave interact with molecules and generate excited H^{2*}. The second part is a filter region for electron separation by a transversal magnet field, the field is created by the filter magnet inside the source. The magnetic strength is about 300 Gs. The third section is the H^- formation region where H^- is generated. A cylinder with a tantalum lining is installed as a collar. As mentioned in reference [2], collar system has many unique abilities that benefit the H^- ion generation. A dipole magnet embedded in plasma electrode was used for electron bending.

The 2.45 GHz microwave driven pure volume effect H^-ion source test was done on ion source test bench of PKU [4]. The IS test bench consists of a compact 2.45 GHz PKU PMECR ion source with its microwave system, a tri-electrode extraction system, a vacuum chamber for beam diagnostic device and a 90 degree dipole analysis magnet with a Faraday cup (FC2). In the vacuum chamber, a Faraday cup (FC1) and a multi-slit single-wire (MSSW) beam emittance monitor are installed. Fig.1 shows the layout of the IS test bench.

In order to adjust the strength of e-dump field, different length of magnets which were put on the top of the ion source were added to adjust the e-dump field. There are three groups I, II, III with different strength of e-dump field 30 Gs, 40 Gs, 55 Gs respectively. The results that pure H^- current was almost the same for three

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groups proved that the outer magnet didn't influence the filter field.

By changing e-dump field and operation pressure within the chamber, a lot of experiments had been carried out to study the H^- source. The operation pressure was changing from 1.5×10^{-3} Pa to 8.0×10^{-3} Pa in a vast range. while other operation parameters kept constant, and the beam was extracted at voltage of 50 kV with 2800 W pulsed RF power feeding in the chamber.

In the series experiments, H^- beam current and H^-/e ratio can not be detected directly, and electron voltage U_e and H^- voltage U_{H-} were the value of the particle respectively detected by FC2 VS pressure through the 90 degree dipole analysis magnet. With beam current I_{beam}, electron voltage U_e and H^- voltage U_{H-}, the H^- current I_{H-} can show as:

$$I_{H^-} = \frac{U_{H^-}}{U_{H^-} + U_e} I_{beam} \qquad (3)$$

The H^-/e ratio can express as:

$$R = \frac{U_{H^-}}{U_e} \qquad (4)$$

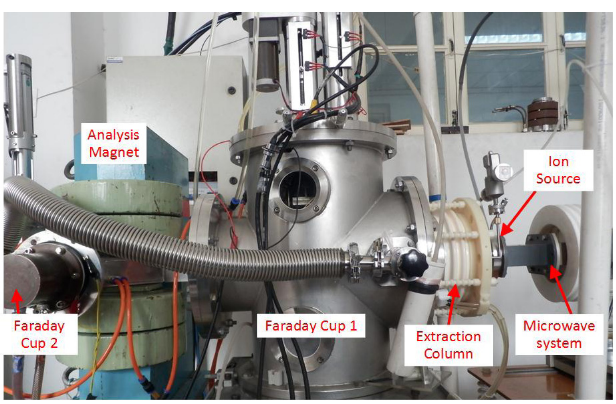

Figure 1: Ion Source Test Bench of PKU

EXPERIMENTAL RESULTS OF H- ION SOURCE

Enhancing microwave power could improve the production of fast electron that was proved in our series experiments, considering the ability of the microwave source in our lab and heat dissipation of ion source, the microwave power was set at 2800W.

The experimental result about operation pressure in the discharge chamber VS H^- beam current was showed in fig.2. There was a big influence of operation pressure on H^- beam current from fig.2, existing an optimum operation pressure for H^- beam current. Enhancing pressure could increase the collision possibility of fast electron with H_2 to boost the production of highly rovibrationally excited molecules H_2* that will transfer into H^- later. When pressure reach a certain value, increasing pressure would reduce the production of H^-, for there would not be enough fast electrons to impact with H_2, and the increasing gas intensity would enhance the possibility of H atoms and molecules destroy H^-. It is critical to choose a pressure balancing those two processes. The range of pressure was vast for the production of H^- in high level, it's robust for operation with pressure fluctuation.

For three groups with different strength of e-dump field to research the performance of e-dump field, the experimental results of operation pressure VS total beam current and operation pressure VS H^-/e were showed in fig.3 and fig.4 respectively. For group I, it had the lowest total beam current and highest H^-/e ratio; group III had the highest total beam current and lowest H^-/e ratio; group II was in the middle. It was obvious that increasing the intensity of e-dump field could reduce total beam current and increase H^-/e ratio, it indicated that increasing the intensity of e-dump field in an appropriate range could dump electron from the extracted beam.

Because a dipole magnet embedded in plasma electrode was used for e^- bending and the outer magnet could enhance the effect of election dumping, the electron within the extracted beam was dumped on the collar, the experimental result that the power load of depression electrode was low and three electrode had not been melt by the extracted beam for more than 100 hours also proved it. The advantage of this design is that the electrons don't have much energy before they are absorbed, it could reduce the power supply of high voltage source, decrease possibility of arcing and slow down water cooling problem.

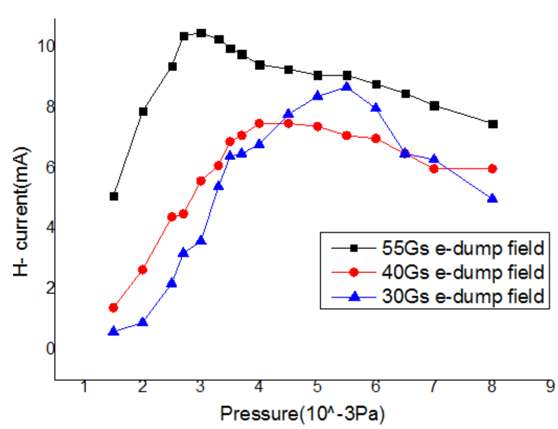

Figure 2: H^- current VS operation pressure

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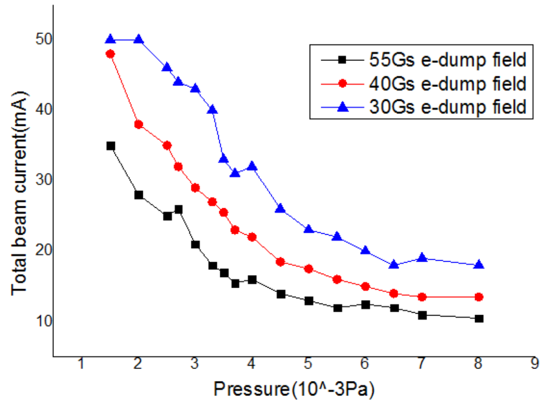

Figure 3: Total beam current of source VS operation pressure

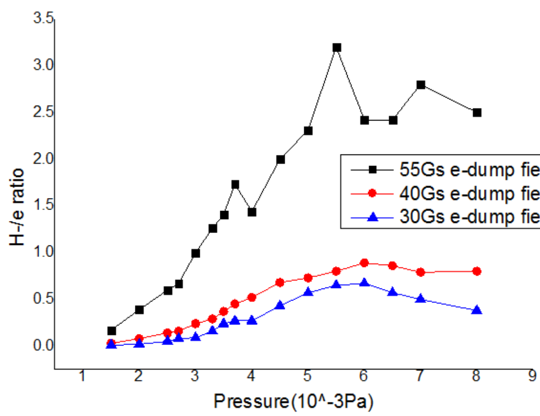

Figure 4: H^-/e ratio VS operation pressure

CONCLUSION

Experimental study was carried out on the developing 2.45 GHz microwave driven pure volume effect H^- ion source at PKU. There exists an optimum operation pressure for H^- beam current by balancing the production of H^- and keeping it from being destroyed. Increasing the intensity of e-dump field in an appropriate range could dump electron from the extracted beam on the collar.

The experimental condition of highest H^- current within the series experiments could be expressed as following:

Table 1: Experimental Condition

Parameter	Experimental value
Operation pressure	2.8×10^{-3} Pa
strength of e-dump field	55 Gs
Microwave power	2800 W
Extraction voltage	50 kV

More study concerning the bias voltage and chamber lining is in progress, and more results will come up with future improvements.

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