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# Intense negative ion source

Yoshiharu Mori
National Laboratory for High Energy Physics(KEK)
Oho 1-1, Tsukuba-shi,Ibaraki-ken 305, JAPAN

ABSTRACT

The volume $H^-$ ion source has been developed at KEK. The $H^-$ beam intensity was enhanced by introducing a very small amount of cesium vapor in the ion source. The extracted $H^-$ beam current of 20mA was obtained in the cesium-mode operation. The measured 90% normalized beam emittance was about 1πmm.mrad for 12 mA beam. It was found that the workfunction of the cesium covered surface of the beam extracting plasma electrode had an important role to enhance the $H^-$ beam intensity.

## I. INTRODUCTION

At KEK, the pulse operated volume $H^-$ ion source has been developed since 1988.[1] It is aiming for a pulsed $H^-$ beam of more than 20mA with a 90% normalized emittance of less than 1 π mm.mrad. One of the difficulties in operation of the volume $H^-$ ion source is its poor efficiency. A relatively large arc current is required to obtain an intense beam current of more than 10mA. Moreover, the total electron drain current from the ion source reaches 100 times of that of the extracted $H^-$beam.

Kao Leung et al have recently found that the extracted $H^-$ beam current could be increased by injecting cesium vapor into the ion source plasma chamber.[2] We have also observed this cesium effect in our volume $H^-$ ion source. The extracted $H^-$ ion beam current was increased more than four times of that before injecting cesium vapor and the extracted $H^-$ ion current reached a maximum of 20 mA. The cesium consumption rate was surprisingly small compared with the surface $H^-$ ion source and this may hence reduce the difficulties described above in operation of the ion source with cesium vapor. We have made several experiments to examine the cesium effect on the volume $H^-$ ion source and found that the surface condition of the beam extracting plasma electrode has a very important role in increasing the $H^-$ beam intensity in the cesium-mode operation.

## II. CHARACTERISTICS AND PERFORMANCE

A schematic diagram of the present test apparatus of the KEK volume $H^-$ ion source is shown in Fig. 1. The ion source consists of a cylindrical plasma chamber which is surrounded by SmCo permanent magnets and a single hot filament cathode. The length and the diameter of the plasma chamber are about 160mm and 100mm, respectively. A pair of SmCo permanent magnets, which make a dipole magnetic field, a so called virtual magnetic filter, are placed at the the outside of the plasma chamber and close to the plasma electrode. The magnetic field becomes maximum at the anode hole. Through the experiment, a single hole of 7.5mm in diameter was used as the anode aperture.

A helical coil shaped $LaB_6$ filament is used as a hot cathode and it is attached on the molybdenum supporting rods which are cooled by water. The operating temperature of the filament is about 1400°C and the lifetime is more than several hundred hours.

Table 1. Typical operating parameters of the KEK volume $H^-$ ion source in cesium-mode operation.

| | |
|---|---|
| ARC CURRENT | 100-200A |
| ARC VOLTAGE | 120-150V |
| FILAMENT CURRENT | 70-80A |
| HYDROGEN FLOW RATE | 15-20sccm |
| BEAM EXTRACTION VOLTAGE | 30-40 kV |

Cesium vapor is injected into the plasma chamber from the outside reservoir through a heated feedthrough. The high temperature valve, which can be closed to stop the cesium feeding immediately after the $H^-$ ion beam current is increased, is located between the ion source and the reservoir. The reservoir temperature is normally 200-250°C.

Typical beam extraction energy is about 30-40 keV. In order to reduce the enormous amount of electrons extracted from the ion source simultaneously with $H^-$ ions, a pair of small permanent magnets making a dipole field

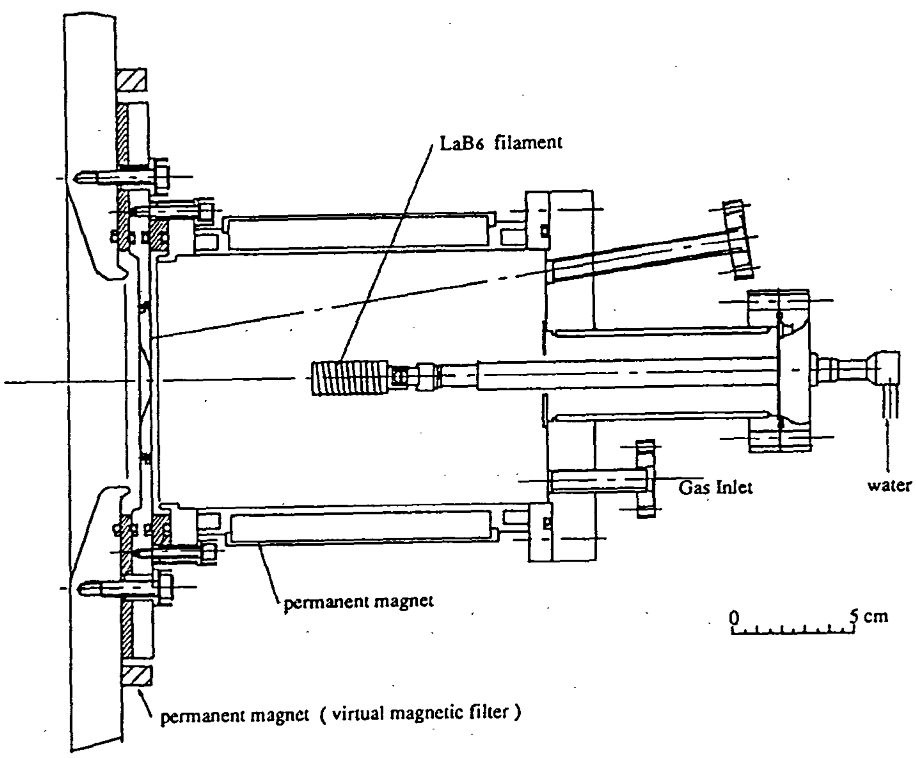


Fig.1 Schematic diagram of the KEK volume H- ion source.

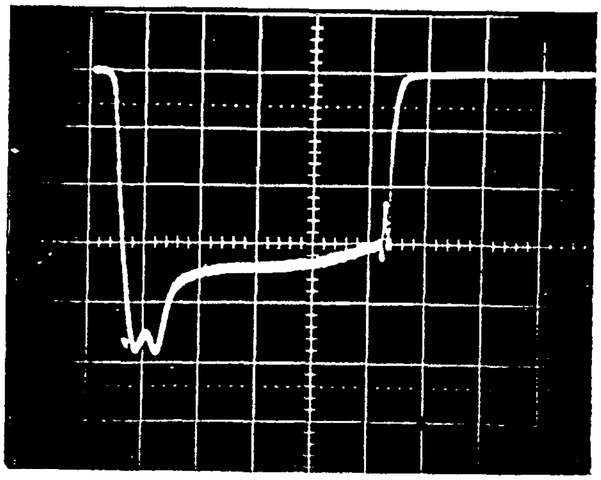

Fig.2-a H⁻ beam waveform before injecting cesium vapor. Vertical axis: 1 mA/div. Horizontal axis: 0.1 msec/div.

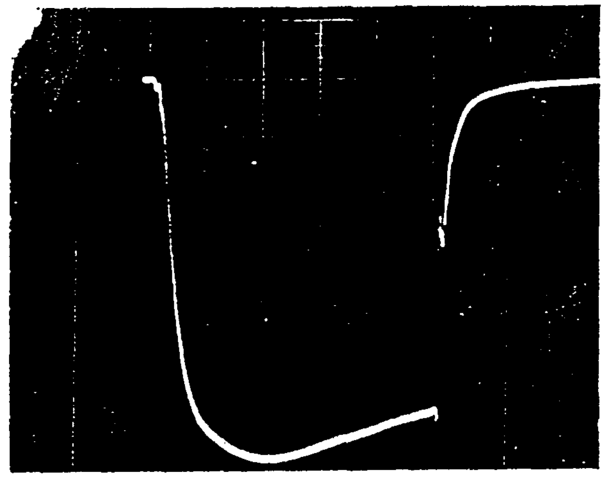

Fig.2-b H⁻ beam waveform after injecting cesium vapor. Vertical axis: 2 mA/div. Horizontal axis: 0.1 msec/div.

at the beam extraction point are placed. The maximum field strength of this dipole magnet is about 300 gauss. The beam can be focused by an einzel lens placed about 20 cm away from the extraction electrode and the another pair of small permanent magnets are also put at the front of the einzel lens to sweep out the electrons completely. In table 1, typical operating parameters of the cesium-mode volume H⁻ ion source are summarized.

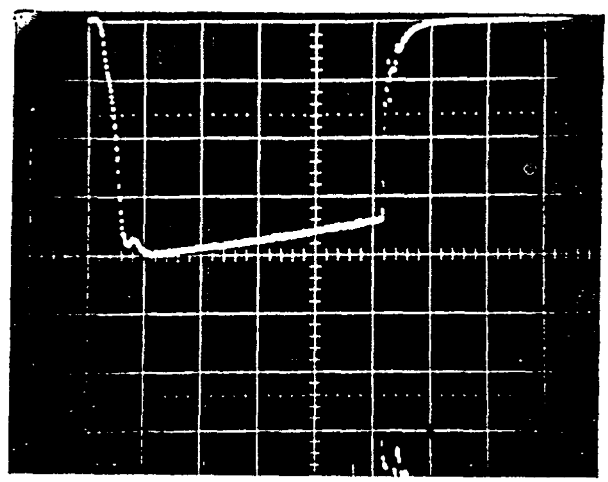

Fig.3 Optimized H⁻ ion beam current. Vertical axis: 5 mA/div. Horizontal

The extracted $H^-$ beam intensity is dramatically changed by injecting cesium vapor into the plasma chamber. Figures 2-a and 2-b show the typical $H^-$ beam waveforms before and after the cesium vapor is injected, respectively. In these figures, the total drain currents($H^-$ + electron) from the ion source are also shown. The $H^-$ beam current is increased from 3mA to 12mA and on the other hand, the total drain current is decreased from 350mA to 100 mA. By optimizing the various parameters of the ion source after the cesium vapor is injected, the $H^-$ ion beam current was increased to 20mA as shown in Fig. 3.

The cesium consumption rate was very small in operating the ion source. For example, once the beam intensity was increased after opening the valve for the cesium feed line, it kept almost constant for several ten of hours even when the valve was closed.

The beam emittance was also measured before and after the cesium injection. The magnitudes of beam emittance were little different before and after the cesium injection when the beam intensities were not so large. However, the beam emittance substantially increased to 1 $\pi$mm.mrad when the beam intensity was increased to 12 mA. This may be explained by emittance growth due to a space charge force in a pulsed beam whose pulse width is too short for a complete space charge neutralization by positive ions generated in ionization of the residual gas.

We have measured workfunction changes of the plasma electrode before and after the cesium injection. The workfunction change was measured by detecting the photo-emission electron current which is generated by a single mode Ar ion laser beam($\lambda$= 514.5nm). We found that the workfunction kept decreasing for long time during the operation of the ion source even after the valve of the cesium feedline was closed. This may relate to the fact that the cesium consumption rate is very small.

In order to examine which surface, the plasma electrode surface or other wall surface, is most effective in generating $H^-$ ions when the cesium vapor is injected, we cleaned the plasma electrode surface only by Ar ion sputtering. Before the Ar ion sputter cleaning, the $H^-$ ion current was 12 mA, however, it decreased to about 3mA just as before the cesium injection and the photo-emission electron current was also disappeared after one hour cleaning. Thus the plasma electrode surface seems to affect very much on the enhancement of the $H^-$ ion production in the cesium-mode operation.

## III. Summary

It was found that the characteristics of the ion source changed dramatically by injecting the cesium vapor into the ion source. More than four times more $H^-$ ion beam current was extracted after the cesium injection and, nevertheless, the cesium consumption rate was very small. By the workfunction measurement with a photo-emission electron technique, it was also observed that the surface condition of the plasma electrode played an important role in the cesium-mode operation.

(REFERENCES)

(1)Y.Mori,A.Takagi,K.Ikegami,S.Fukumoto; 4th Int. Symp. on Production of Neutralization of Negative Ions and Beams,BNL ,1986, AIP conf. series,page378.

(2)K.N.Leung et al;Rev.Sci.Instr.,60(1989)531.

Q(I.Yamane): What is the energy of the $H^-$ beam in the last figure? If the energy of the $H^-$ beam is increased, does the emittance growth decrease?

A(Y.Mori): The beam energy is assumed to be 30KeV. The emittance growth can be reduced by increasing the beam energy.

Q(A.Noda): Have you ever studied about the effect of Cesium introduced into Volume production ion source to the break down voltage in the following accelerator? Does such voltage not go down?

A(Y.Mori): Very small amount of Cesium consumption is enough for increasing the $H^-$ beam intensity, therefore, it might not necessary to worry about the break-down in a post-accelerator.

Q(I.S.K.Gardner): What is the current density at the output of the $H^-$ source before and after the cesium addition.

A(Y.Mori): The $H^-$ beam current density was ~10$\mu A/cm^2$ before Cs injection and ~60$\mu A/cm^2$ after Cs injection.