# OPTIMIZATION OF AN RF DRIVEN H- ION SOURCE

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*Abstract*

A radio-frequency driven multicusp source has recently been developed to generate volume-produced $H^-$ ion beams with extracted current density higher than 200 mA/cm$^2$. We have improved the output power of the rf generator and the insulation coating of the antenna coil. We have also optimized the antenna position and geometry and the filter magnetic field for high power pulsed operation. A total $H^-$ current of 30 mA can be obtained with a 5.4-mm-diam extraction aperture and with an rf input power of 50 kW.

## I. INTRODUCTION

Multicusp plasma generators have been operated successfully both as volume production or surface conversion $H^-$ sources.[1] The $H^-$ ions generated by volume-production processes have lower beam emittance and therefore are useful for the generation of high-brightness beams. In order to achieve high current densities, volume $H^-$ sources require high discharge power. For this reason, the lifetime of the ordinary filament cathodes is short for steady-state or high repetition rate pulse operations.

A new radio-frequency (rf) driven $H^-$ source[2] has recently been developed at Lawrence Berkeley Laboratory (LBL) for use in a calibration beam system and possibly in the injector unit of the Superconducting Super Collider (SSC). Initial study showed that rf power as high as 25 kW could be coupled inductively to the plasma via a glass-coated copper-coil antenna. It has also been demonstrated that the source is capable of generating 1-ms $H^-$ beam pulses with a repetition rate as high as 150 Hz.

Experiments have been conducted at LBL to improve the efficiency and reliability of the source, and the $H^-$ to electron ratio in the extracted beam by optimizing the filter magnetic field, the position and geometry of the antenna and the extraction aperture configuration. To date, it has been demonstrated that rf power higher than 50 kW could be coupled to the plasma via an improved porcelain-coated antenna. The extracted $H^-$ current achieved is higher than 30 mA.

## II. EXPERIMENTAL SETUP

Figure 1 is a schematic diagram of the ion source. The source chamber is a thin-walled copper cylinder (10 cm diam by 10 cm long) surrounded by 20 columns of samarium-cobalt magnets that form a longitudinal linecusp configuration. The magnets, in turn, are enclosed by an outer anodized aluminum cylinder, with the cooling water circulating around the source between the magnets and the inner housing. The back flange has four rows of magnets cooled by drilled water passages in the copper. In order to enhance the $H^-$ yield, a pair of water-cooled permanent magnet filter rods is installed near the extraction region.

The open end of the source chamber is enclosed by a two-electrode extraction system. $H^-$ beams are normally extracted from the source through a 2-mm-diam aperture. a permanent-magnet mass analyzer is used with a Faraday cup to measure the electron and the $H^-$ currents in the accelerated beam. In order to reduce the electron contents in the beam, a stainless-steel cylindrical collar[3] is installed at the exit aperture (Fig. 1). This collar is capable of reducing the electron current by a factor of 2 without any degradation in the $H^-$ output current.

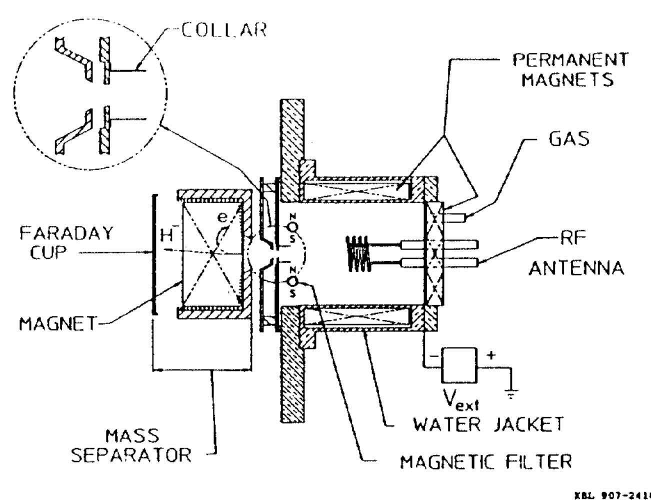


Fig. 1 Schematic diagram of the rf multicusp $H^-$ ion source.

The rf antenna is fabricated from 4.7-mm-diam copper tubing and is coated with a thin layer of hard porcelain material. This new porcelain- coating performs better than the glass-coating which we used in the previous experiments. The thin coating is slightly flexible and is therefore resistant to cracking. It can maintain a clean plasma and can last for a long period of operation.

A sine-wave oscillator drives a gated 400 W solid state amplifier at a nominal operating frequency of 1.8 MHz. The resulting rf pulses then drive a Class C tube amplifier with a maximum pulse output power of 50 kW. In order to couple the rf power efficiently into the source plasma, a matching network (which is a tunable resonant parallel LC circuit) is employed. In this experiment, a small hairpin tungsten filament is used as a starter for the rf induction discharge.

## III. EXPERIMENTAL RESULTS

The multicusp source is equipped with a pair of neodymium-iron magnet filter rods which are placed 5 cm apart. The maximum field at the center of the filter plane is about 125 G. As we reduce the filter separation to 4 cm, the magnetic field is increased to about 190 G. With this new filter arrangement, we are able to obtain higher $H^-$ output and lower electron current in the extracted beam. All the source optimization data reported in this paper are obtained with this filter geometry.

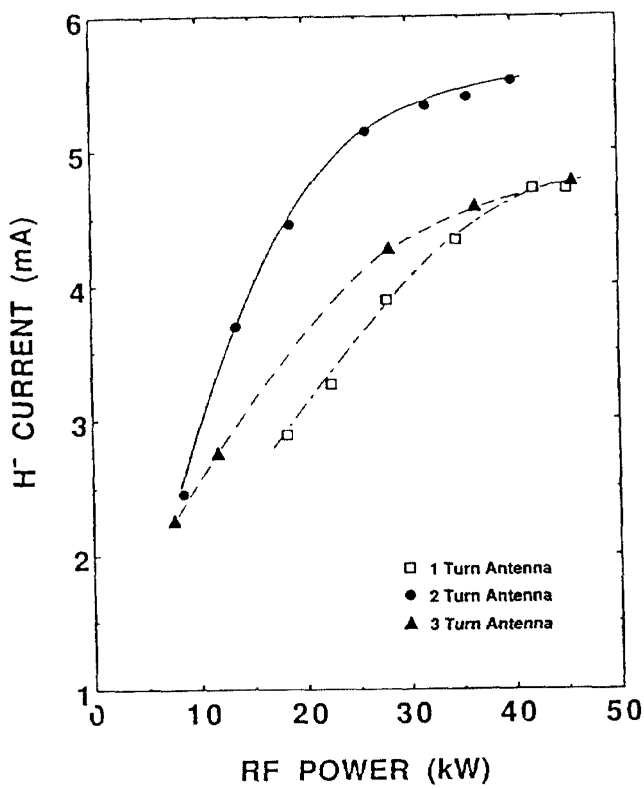


Fig 2. $H^-$ output as a function of rf power for three different antenna geometries.

Figure 2 shows the $H^-$ output current as a function of rf input power for 1, 2 or 3 turn antenna coil. Within the range of rf power considered, the 2-turn antenna provides more $H^-$ current than the 3 or 1-turn antenna. The diameter of the antenna coil can also affect the $H^-$ yield. We have tested two different diameter antenna coils (5.3 cm diam and 7 cm diam), both having the same number of turns. Figure 3 is a plot of the extracted $H^-$ current versus rf input power. The 7-cm-diam coil improves the $H^-$ output by approximately 18%.

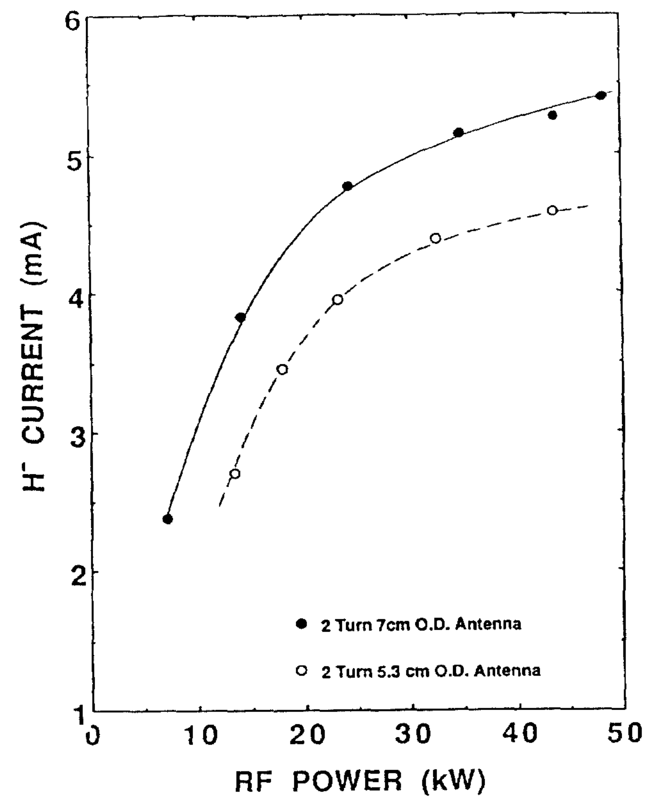


Fig. 3 $H^-$ output as a function of rf power for two different diameter antenna coils.

The dependence of the $H^-$ output current on the axial position of the antenna has been investigated. Since the antenna is supported through two slidding seals on the back flange, the position of the antenna can be easily varied without opening the source chamber. Figure 4 shows the $H^-$ current as a function of rf power for three different axial positions. (The distance is measured from the back flange surface to the end of the antenna). It can be seen that the extractable $H^-$ current increases as the antenna approaches the filter. The optimum position occurs at about 8.35 cm. Further increase in the distance from the back flange results in a reduction of the $H^-$ current.

The scaling of $H^-$ current as a function of extraction area is of great interest in $H^-$ source development. By using the optimized filter geometry and position, we have operated the source with a 5-mm-diam and a 5.4-mm-diam extraction aperture. Figure 5 shows the dependence of the extracted $H^-$ current as a function of rf power. With a 5-mm-diam aperture, the highest $H^-$ current achieved is about 26 mA. By enlarging the aperture diameter to 5.4 mm, the $H^-$ output current can exceed 30 mA for an rf input power of 50 kW. The required source operating pressure is approximately17 mTorr.

The present result as well as the data from the previous investigation have demonstrated that the rf driven volume-production source can provide substantial $H^-$ current. Recent experimental measurement also shows that the beam emittance is nearly the same for both the rf and filament dc discharge for a given input power.[4] For this reason, the rf induction driven source is extremely useful for the production of high brightness $H^-$ beams.

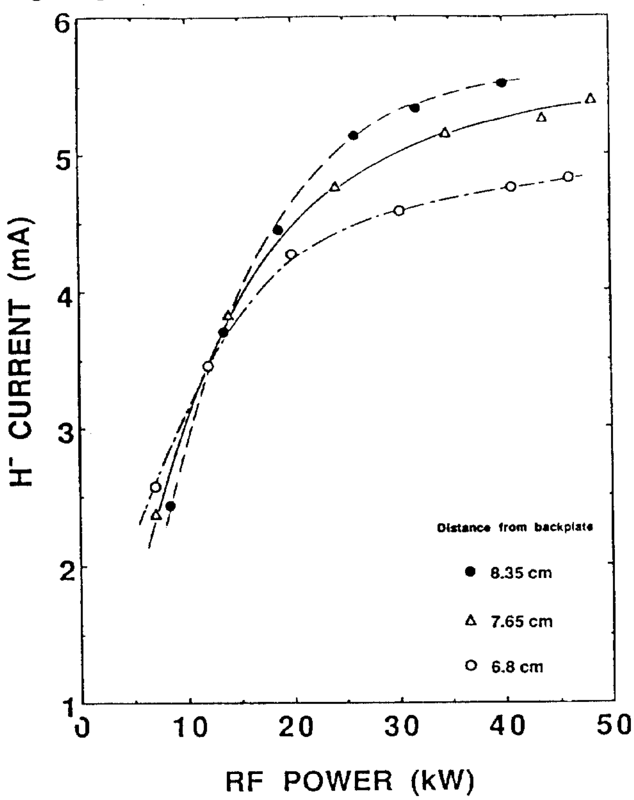


Fig. 4 $H^-$ output as a function of rf power for three different antenna positions.

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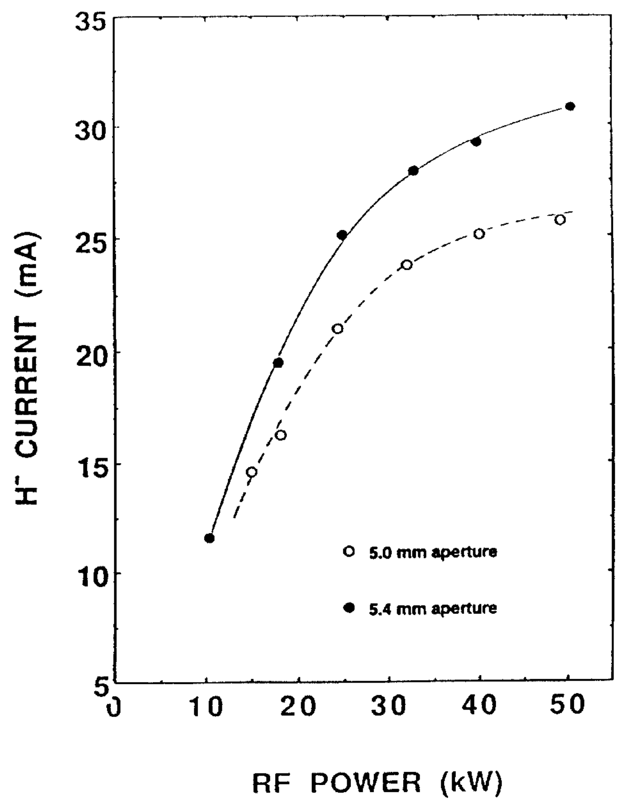


Fig. 5 $H^-$ current versus rf input power for two different extraction aperture sizes.