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THE TRIUMF COMPACT DC H^-/D^- ION SOURCE

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Abstract

A compact dc H^-/D^- ion source using multicusp magnetic plasma confinement, has been experimentally studied and optimized on the TRIUMF ion source test stand. The plasma parameters have been obtained with rapid computer controlled Langmuir probe scans. The extraction electrode configuration, originally tailored to the TR30 cyclotron requirements, has been further developed. With a 12mm diameter extraction hole this source now provides 9 mA within a normalized emittance of 0.44 π mm-mrad and can be easily modified for lower currents of smaller emittance (1mA H^- current with normalized emittance 0.12 π.mm-mrad or 7mA H^- current with normalized emittance 0.34 π.mm-mrad).

The source has proven to have low maintenance, high reliability and long filament lifetime. This paper emphasizes basic plasma parameters which determine the efficiency of H^-/D^- production. Some experimental results obtained from several versions of the extraction system are also described.

Introduction

Modern accelerator technology requires high intensity H^- and D^- beams of low emittance. For more than a decade TRIUMF Ion Source Group has developed H^- sources for the 500 MeV cyclotron and the other accelerators. A compact DC H^- ion source[1] was designed and developed for high intensity operation of the 500 MeV cyclotron and slightly modified for the TR30 isotope production cyclotron. Initial design criteria for this TR30 cyclotron were 5.0 mA H^- current within a normalized emittance of 0.35 π.mm-mrad.

A multicusp plasma confinement with a magnetic filter produces the high brightness negative beam. It is known that volume and surface production are the most effective methods to enhance the production of H^- and D^- ions[5]. According to the calculation by Wadehra and Bardsley[3] most H^- are produced from the $\nu = 4$ vibrational state molecules through the reactions.

$$H_2^* + e^-(\sim 0.5eV) \rightarrow H_2^-(\tau \sim 10^{-12}sec) \rightarrow H^- + H_0.$$

This paper presents some of the results from our investigation of the basic parameters in the multicusp confined plasma and the role of the extraction system to the beam current and to the beam emittance. To investigate the plasma, a Langmuir probe technique was used as it is still one of the most reliable methods available. Emittance was measured by using a LAMPF developed method with electrostatic deflecting plates.

Source description

A schematic of the cusp source is shown in Fig. 1. A copper cylinder (10 cm diam by 15 cm long) surrounded by 10 rows of $SmCo_5$ magnets serves as a plasma chamber. Four parallel magnets installed in the back flange provide continuity of the cusp field. Flipping the polarity of the last magnets in a pair of diametrically opposed rows creates a strong virtual magnetic filter which separates the plasma chamber into high and low energy electron regions. Two additional pairs of small magnets are installed in the second electrode in order to sweep out any electrons which are extracted.

An axially-symmetric four-electrode extraction structure which produces a 25 keV beam is chosen as an extraction system. Three versions of the extraction system were studied and optimised to have minimum emittance and maximum current.

Langmuir probe measurements

A cylindrical Langmuir probe (0.5mm diam x 5mm long tungsten wire) is driven along the center axis of the source by a stepping motor controlled by a Vax through CAMAC. In order to get reliable measurements from the Langmuir probe an iterative method is used.[2] Probe disturbances and heating problems were reduced by using a small probe and making fast measurements. The Vax based program takes 14,000 data within a few seconds. At the end of the each step a ramp voltage was given to the probe and digitized probe current transfered to the Vax as an I-V curve. After storing the data the probe returns to a safer region. Many scans are obtained to reduce errors.

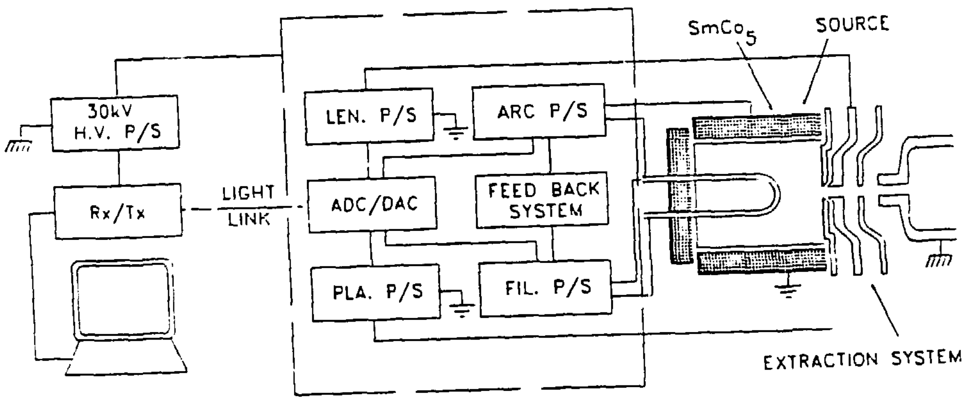

Fig 1. Schematic of the source

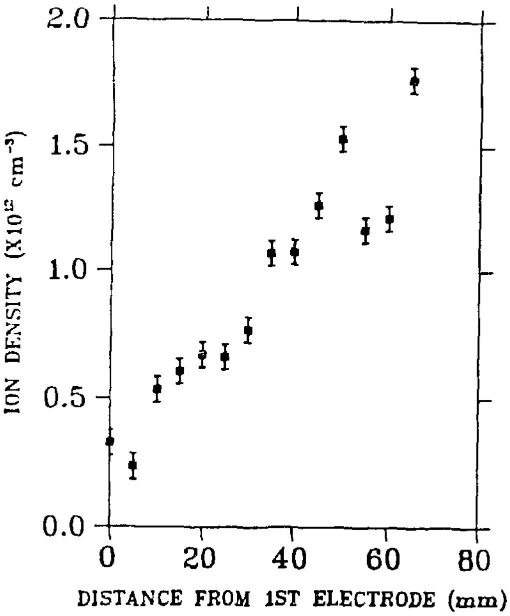

Fig. 2 Variation of the ion density on distance from the first electrode.

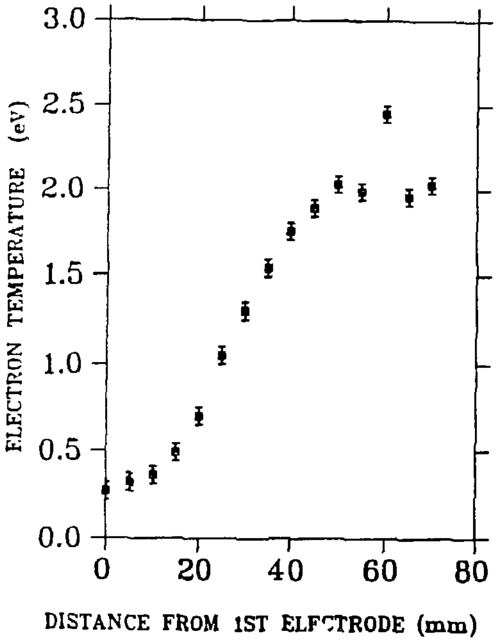

Fig. 3 Variation of the plasma temperature on distance from the first electrode through the axis of the source.

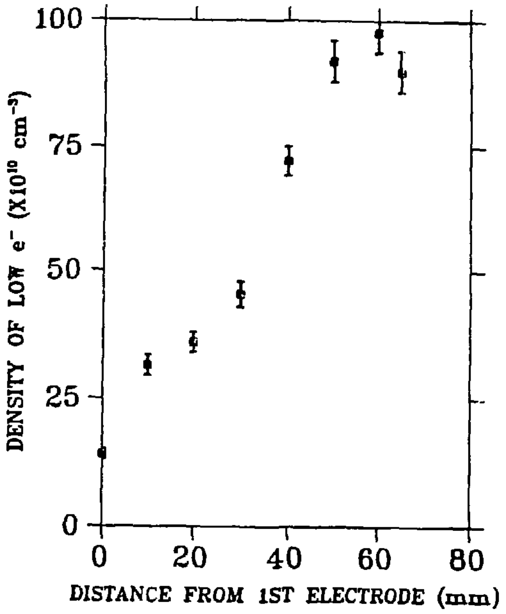

Fig. 4. Variation of the low energy electron density on distance from the first electrode through the axis of the source.

To calculate the plasma potential, temperature and density, Laframboise theory[6] was used. It gives the ratio of the probe radius to the electron Debye length, R_P/λ, which depend on kT_e and n_e. A first approximation of kT_e is obtained from the I-V curve and the plasma potential is determined from it's derivative. The ion density is given by

$$n_+ = \frac{4I_+(\chi)}{eA(8kT_e/\pi m_+)^{1/2} f(R_p/\lambda,\chi)} \qquad (1)$$

The final results are determined by iteration. The variation of the ion density and plasma tempereture as a function of the distance from the first electrode are shown in Fig. 2. and Fig. 3. The variation of the density of low energy electrons at the optimum beam current has also been deduced, and is shown in Fig. 4.

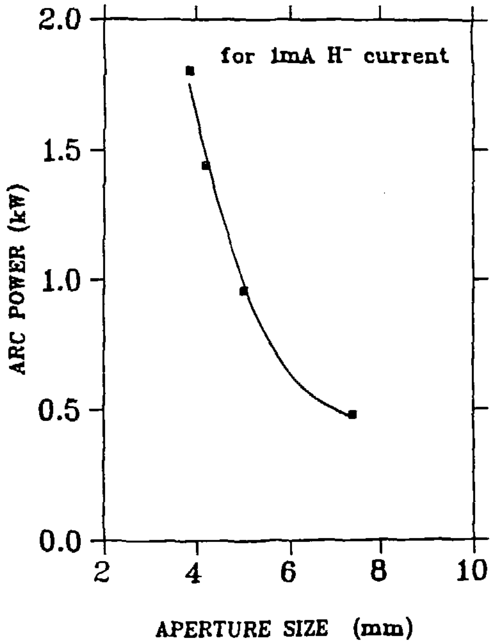

Fig. 5 Necessary arc power to obtain 1mA H$^-$ current for various apertures of the first electrode

Beam emittance measurements

The emittance scanner consists of two electrostatic deflection plates, (2.8mm gap by 38mm long) located between two narrow (0.06mm) slits, and a Faraday cup. The scanner is moved transversely across ion beam under computer control. At each position the beam current on the Faraday cup is obtained as a function of the electric field at the deflection plates.

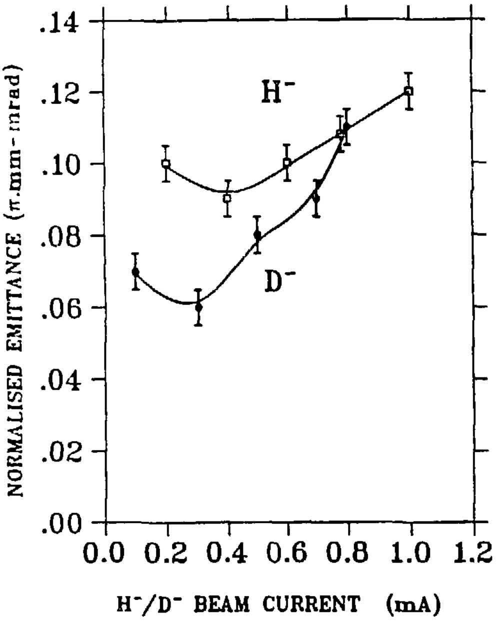

Fig. 6 Normalised emittance versus the extracted ion current up to 1mA

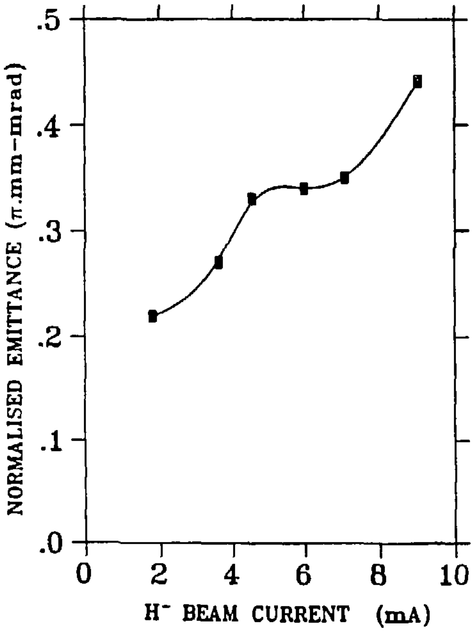

Fig. 7 Normalised emittance versus the extracted beam current up to 9mA

Three electrode aperture combinations were used as follows: a) For beam current up to 1mA, diameters of 4mm and 3.5mm were used in first and second electrodes. b) From 1mA to 7mA, electrodes had 11mm and 10mm aperture. c) Greater than 7mA, both electrodes had a 12mm aperture.

With system a) the normalized emittance for a 1mA H$^-$ current at 25keV is 0.12π.mm-mrad, and for 0.7mA D$^-$ current the emittance is 0.09π.mm-mrad. It is necessary to increase either the aperture or the arc power to achieve more current. Fig. 5. shows the arc power necessary to obtain 1mA H$^-$ for various apertures of the 1st electrodes. Fig. 6. shows the emittance versus the extracted ion current up to 1mA and in Fig. 7. up to 9mA of H$^-$. Fig. 8. shows dependence of the extracted H$^-$ and D$^-$ current on arc power for the 12mm aperture. Due to a high electron current, the D$^-$ beam current could only be measured up to 3.4mA.

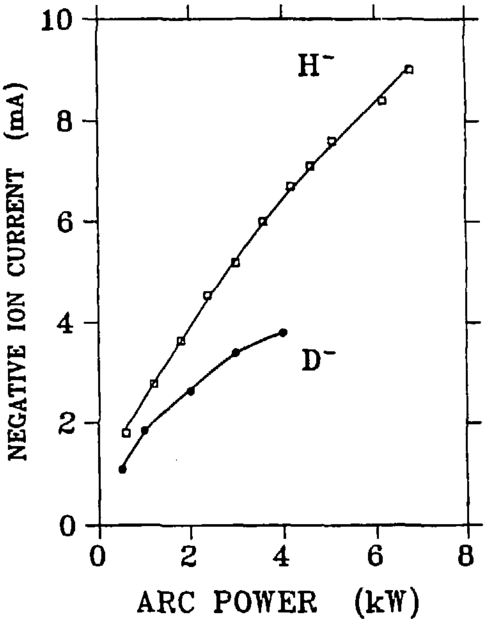

Fig. 8. Extracted H$^-$/D$^-$ beam current versus arc power.

Reference

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