DEVELOPMENT OF A HIGH BRIGHTNESS ION SOURCE FOR THE PROTON LINEAR ACCELERATOR (BTA)

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A prototype ion source has been designed and tested for the 10 MeV, 10 mA, CW proton linear accelerator called Basic Technology Accelerator (BTA), which is to be constructed at JAERI. The ion source consists of a multicusp plasma generator and a two-stage ion extractor, and is expected to produce 100 keV, 120 mA proton beam with a normalized beam emittance of as low as 0.5 πmm.mrad. The first experiment was conducted at a 60 kV test facility. A convergent ion beam of 60 keV, 57 mA, of which perveance is higher than that of 100 keV, 120 mA, was produced continuously with an e-folding half-width divergence of 10 mrad. The normalized beam emittance of 0.45 πmm.mrad (90%) was obtained. The proton ratio was measured by Doppler-shifted spectroscopy and a momentum mass analyzer, and was found to be more than 80 %.

1. INTRODUCTION

A 10 MeV linear accelerator called Basic Technology Accelerator (BTA) will be constructed at JAERI. The objective of the accelerator is to develop the basic technologies required for the construction of the 1.5 GeV linear accelerator, which is being proposed for use in the accelerator-driven nuclear transmutation system as one of the option of OMEGA project.

The target of the BTA is to accelerate 100 mA proton beams to 10 MeV with a duty cycle of 10 %. For this accelerator, it is necessary to develop the ion source that produces intense hydrogen beams with a low beam emittance and a high proton yield. Basic specifications proposed for the ion source are listed in Table I.

Table I Basic Specifications of the Ion Source

Energy	100 keV
Current	120 mA
Duty Factor	CW
Emittance	0.5 πmm.mrad
Proton Ratio	>90 %
Impurity	<1 %

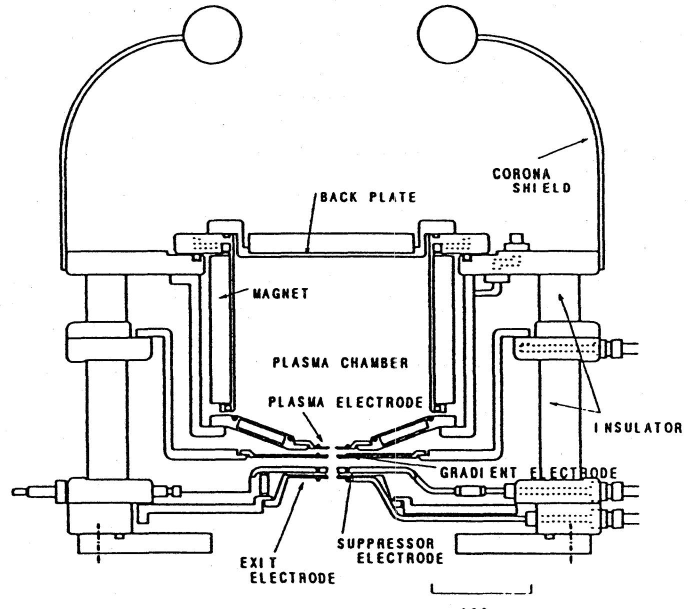

Fig. 1 Cross-sectional view of the prototype ion source for BTA

A prototype ion source has been designed and fabricated. The detailed design was presented in the Ref.1 with the calculations on beam optics, proton yield and source plasma confinement. The first experiment of the prototype ion source was conducted in the ITS-2M Test Stand, which is usually used for the development of the ion sources for fusion application. In the present paper, we describe the main results on the first experiment.

2. Ion Source and Experimental Set-up

The prototype ion source is shown in Fig. 1. The plasma chamber, whose dimensions are 20 cm in diam. and 17 cm in depth, is surrounded by 10 columns of strong SmCo magnets for plasma confinement. The extractor is composed of four electrodes forming two-stage extraction system, that is, extraction-acceleration-deceleration system. The field intensity ratio, f, which is an important parameter in the two-stage extractor and is defined by the ratio of the electric field of the extraction stage to that of the acceleration stage, was chosen to be 0.54 in the present experiment.

Hydrogen ions were produced by arc discharge, extracted from a single aperture of 8 mm in diam., and accelerated to the maximum energy of the test stand, 60 keV, with a long pulse duration of up to one hour. The beam profile was measured by a multi-channel calorimeter located at 2 m downstream of the ion source.

3. Experimental Results and Discussion

Figure 2 shows the beam divergence as a function of beam current for various acceleration voltages. The optimum current which gives the minimum beam divergence for each voltage increases with the acceleration voltage as expected by the Child-Langmuir law, showing a good agreement with the trajectory calculation[1]. A convergent ion beam of 60 keV, 56 mA, of which perveance is higher than that of 100 keV, 120 mA proton beam, was produced with an e-folding half-width divergence of 10 mrad. Assuming the beam diameter was 4 mm at the exit of the ion source, we estimated the normalized emittance was less than 0.5 πmm.mrad (90%). This estimation

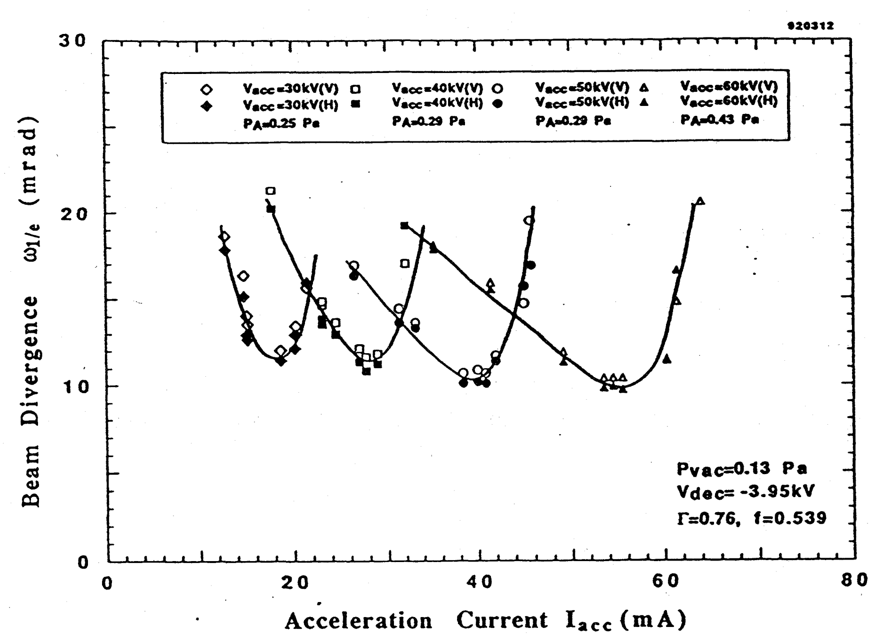

Fig.2 Beam divergence as a function of beam current for various acceleration voltages. The field intensity ratio was kept to be 0.54.

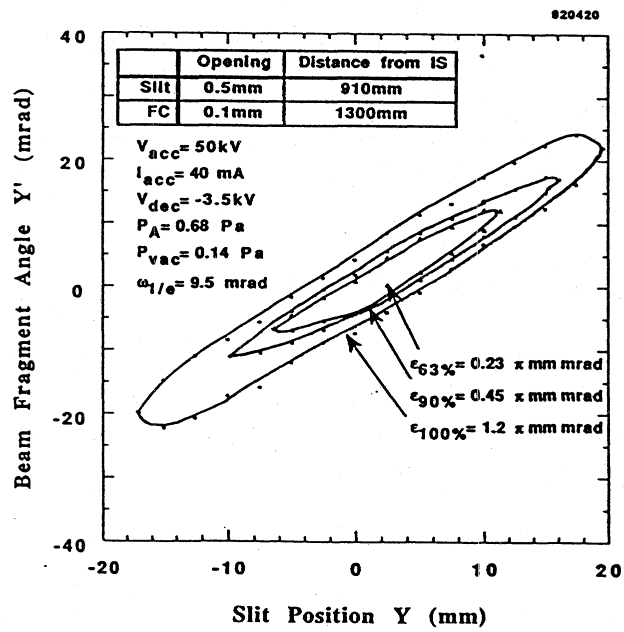

Fig. 3 Emittance diagram at 50 keV, 40 mA. The emittance was measured by a set of the slit and the Faraday cup located at 910 mm and 1300 mm, respectively.

was confirmed by the emittance measurement. Figure 3 shows an example of emittance diagram obtained at 50 keV, 40 mA. The normalized emittance is 0.45 πmm.mrad (90%), which satisfies the specification of BTA.

The hydrogen ion beam contains not only H^+ ions (protons) but also molecular ions such as H_2^+ and H_3^+. Higher proton ratio is preferable for the accelerator application. To enhance the proton yield, the ion confinement in this source is improved by strong magnetic line cusps so that the produced molecular ions are confined for enough time to dissociate to protons. The proton ratio in the beam was measured by a Doppler−shifted spectroscopy and a momentum mass analyzer. Both measurements gave the same result that the proton ratio is as high as 80 % at 50 mA. Since the proton ratio is increasing with the beam current, the proton ratio of nearly 90 % will be achievable.

Although the source plasma was created by arc discharge in this experiment, plasma production by RF is desirable for making the life time longer. For this purpose, we have tried to generate the source plasma by RF in a multicusp plasma generator which has the same dimension as the prototype ion source. By applying 2 MHz, 20 kW RF to the antenna inserted in the plasma generator, a high density hydrogen plasma of $n_e = 5 \times 10^{11}$ cm^{-3} (J_{is}=120 mA/cm^2) was produced.

We are now constructing a test stand that has a power supply f 100 kV, 200 mA. Using this test stand, full energy test will be conducted in the end of 1992.

Reference

1) Y. Okumura and K. Watanabe, Japan Atomic Energy Research Report JAERI−M 92−024 (1992).