Status of the R&D for the Basic Technology Accelerator in JAERI

K. Hasegawa, M. Mizumoto, H. Oguri, H. Murata[1], K. Sakogawa[2],
J. Kusano, M. Kawai[3], Y. Okumura, T. Ono and H. Yokobori[4]
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki, 319-11

Abstract

The Basic Technology Accelerator (BTA) is a proton linear accelerator with an energy of 10 MeV and a current of 10mA. The R&D works for the BTA are in progress. In this report, present status of the R&D for the BTA is described.

Introduction

The Japan Atomic Energy Research Institute (JAERI) is performing a long-term research and development works for partitioning and transmutation of minor actinides and long-lived fission products under the national program called OMEGA (Options Making Extra Gains of Actinides and Fission Products)[1]. A high intensity proton linear accelerator (ETA: Engineering Test Accelerator) with an energy of 1.5GeV and an average current of 10 mA has been proposed to perform the various engineering tests for the transmutation system[2]. For such a high intensity accelerator, it is particularly important to minimize the beam losses to avoid damage and activation of the accelerator structures. An accelerator (BTA: Basic Technology Accelerator) with an energy of 10 MeV and an average current of 10 mA is designed and will be built as a first step in the ETA development, because the beam quality and maximum current are mainly determined by the low energy portion of the accelerator.

The R&Ds for the main accelerator components such as high current hydrogen ion source, radio-frequency quadrupole (RFQ), drift tube linac (DTL) and RF power source are in progress. This report describes the status of the R&D for the BTA.

The basic specification of the BTA is given in Table 1. The beam energy for the BTA is chosen to be 10 MeV to avoid the proton induced reactions in the accelerator structural materials. The acceleration frequency of 201.25 MHz is selected both for the RFQ and the DTL mainly due to the relatively manageable heat removal problems and the availability of the RF source.

Table 1 Basic Specification of the BTA

Accelerated particle	proton
Output energy	10 MeV
Operation mode	pulse
Duty factor	10 %
Peak beam current	100 mA
Average beam current	10 mA

1. Sumitomo Heavy Industries, LTD.
2. Mitsubishi Heavy Industries, LTD.
3. Toshiba Corporation
4. Mitsubishi Atomic Power Industries, Inc.

Ion Source

Fig. 1 shows a cross sectional view of the ion source[3]. The source consists of a multicusp plasma generator with four tungsten filaments and a two stage extractor. The dimension of the plasma chamber is 20 cm in diameter and 17 cm in length. Measured beam current as a function of acceleration voltage (perveance curve) is shown in Fig. 2. The high brightness hydrogen ions of 140 mA were extracted using the 100 kV power supply. The beam profile was measured with a multi-channel calorimeter and the observed normalized emittance was 0.45πmm.mrad (90%). The proton ratio and impurity were also obtained to be 80 % and less than 1%, respectively, by a Doppler shifted spectroscopy method.

Table 2 Specification of the ion source

Energy	100 keV
Current	120 mA
Duty factor	CW
Emittance	0.5 πmm.mrad (normalized 100%)
Proton ratio	> 90%
Impurity	< 1%

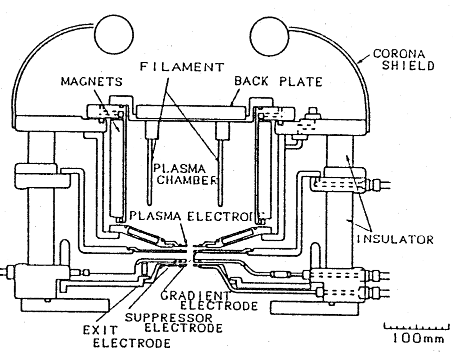

Fig. 1 Cross sectional view of the ion source

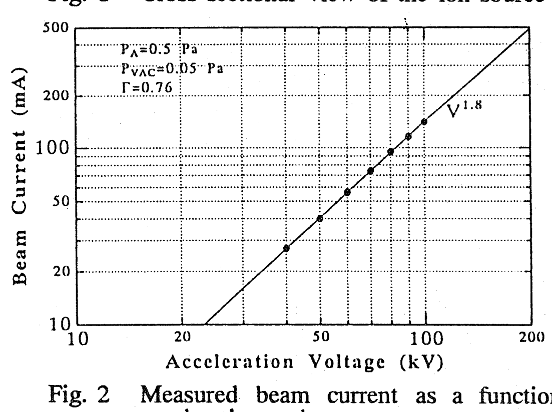

Fig. 2 Measured beam current as a function of acceleration voltage

RFQ

The design study for the RFQ has been made for a four–vane type resonator[4]. The RFQ parameters are given in Table 3. The peak current of 110 mA and duty factor of 10 % were chosen to obtain 10mA average current. Two dimensional machining of the vane (circular cross section of the tip) for the RFQ was examined and its effects were estimated with the modified PARMTEQ code. The undercutting and power losses at the end region of the vanes were studied with the MAFIA code system. The temperature distribution and thermal displacement were estimated with the three–dimensional finite element modeling code of ABAQUS. The vanes are made of oxygen free copper with two cooling water channels (ϕ22mm and ϕ15mm). Water flow through each channel is 30 l/min, and average temperature is 25.5°C. Fig. 3 shows a temperature distribution and displacement on the surface of the vane. Calculated maximum temperature is 39.1°C, and displacement in the transverse and longitudinal directions are 33μm and 99μm, respectively. These deformations are small enough both for the frequency tuning and for the beam dynamics.

The machining of the vanes and the tank have been completed and the ports for an RF input coupler and vacuum devices are being fabricated by the Sumitomo Heavy Industries, LTD. Fig. 4 shows the photograph of the RFQ tank under the vacuum test. The electromagnetic field measurement will be carried out in the next stage.

Table 3 Parameters of the RFQ

Frequency	201.25 MHz
Energy	0.1 – 2 MeV
Beam current	110 mA
Duty factor	10 %
Intervane voltage	0.113 MV (1.8E_k)
Synchronous phase	–90° – –35°
Vane length	334.8 cm
Cavity diameter	36.6 cm
Quality factor	13000 (100%Q)
Wall loss power	432 kW (60%Q)
Beam power	209 kW

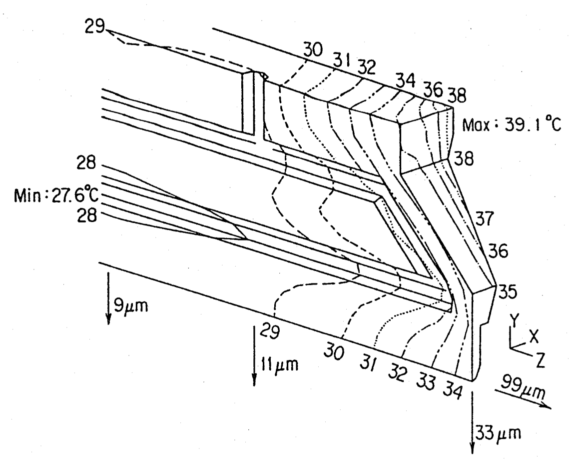

Fig. 3 Temperature distribution and displacement of the RFQ vane

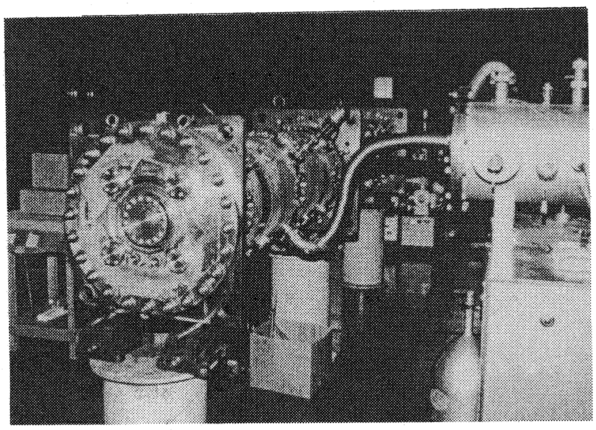

Fig. 4 Photograph of the RFQ tank under the vacuum test

DTL

A resonant frequency, magnetic field strength and heat removal problem were investigated for the DTL under the various mechanical constraints. The beam dynamics design calculations for the DTL have been made with the computer code of PARMILA. The DTL parameters are given in Table 4. An electromagnetic quadrupole using a hollow conductor (5mmx5mm) was chosen for the focussing magnet, of which field is 80 T/m with 5.5 turns of 780 amperes. Two quadrupole magnets were fabricated and examined. The magnetic center position and the higher harmonic field components in the quadrupole magnet were measured with the conventional rotating coil and FFT technique. Fig. 5 shows the photograph of the quadrupole magnet and the rotating coil. The distance from the mechanical center and the magnetic center is less than 30 μm. The measured dipole intensity is shown in Fig. 6.

In the R&D stage, a high power test model with 9 cells is fabricated by Mitsubishi Heavy Industries, LTD. The cross sectional view of the model tank is shown in Fig. 7.

Table 4 Parameters of the DTL

Frequency	201.25 MHz
Energy	2 – 10 MeV
Beam current	100 mA
Average field	2 MV/m
Tank diameter	89.3 cm
Tank length	564.9 cm (full tank) 100.55 cm (model tank)
DT outer diameter	20 cm
DT bore radius	1 cm
Synchronous phase	–30°
DT cell number	36 (full tank) 9 (model tank)
Focus magnetic field	80 – 35 T/m
Quality factor	69800 (100%Q)
Wall loss power	720 kW
Beam power	800 kW

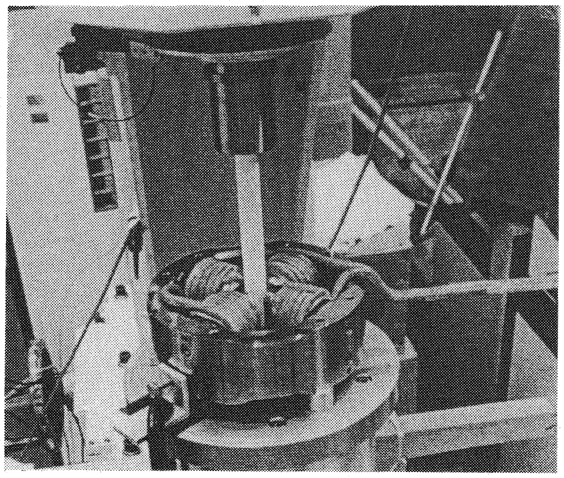

Fig. 5 Photograph of the quadrupole magnet and the rotating coil

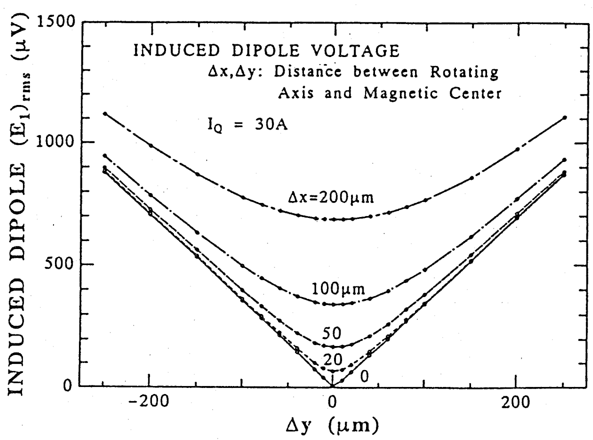

Fig. 6 Induced dipole voltage in the rotating coil as a function of the distance from the magnetic center Δy for five Δx case

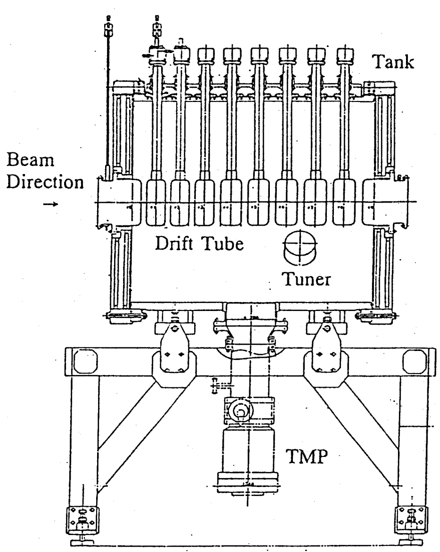

Fig. 7 Cross sectional view of the DTL high power model tank

High power RF source

Three sets of 201.25 MHz RF power sources with 1 MW peak and 12–20% duty are required for the BTA. The block diagram of the RF amplifier is shown in Fig. 8. The tetrode 4CM2500KG (EIMAC), which was originally developed for the fusion plasma heating, is used as an HPA (High Power Amplifier) with a multistage amplifier configuration. The accelerator voltage and phase control loop with an accuracy of <0.1% in amplitude and <1° are prepared. The RF source was designed and one set of the amplifier is manufactured in the R&D stage by the Sumitomo Heavy Industries, LTD. The dummy load test for the HPA will be conducted this summer.

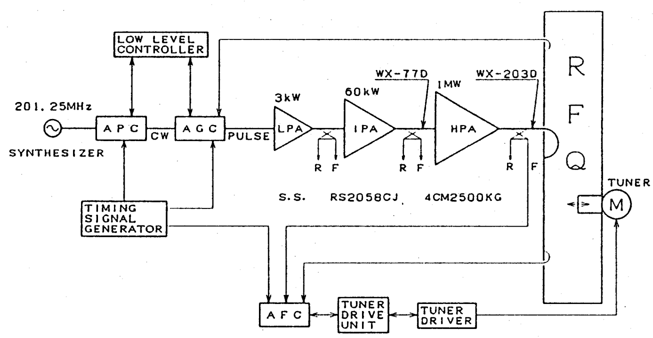

Fig. 8 Block diagram of the RF source

Summary

The R&D works with the design and the construction of the prototype accelerator structures (Ion source, RFQ, DTL and RF source) for the high power test are in progress. For the high power test, measurements of the electric and magnetic characteristics of the accelerator structure will be conducted using the single unit of high power RF source. Problems of the heat dissipation and heat removal in the structure are carefully studied. The detailed design works for the BTA construction are followed in the next stage based on the results of the R&D works.

References

[1] Y. Kaneko, "The Intense Proton Accelerator Program", The 2nd Int. Symp. on Advanced Nuclear Energy Research, Mito, 1990, pp.25–33

[2] M. Mizumoto *et al.*, "High Intensity Proton Accelerator for Nuclear Waste Transmutation", 1992 Linear Accelerator Conference, Ottawa, Canada, AECL–10728, pp.749–751

[3] Y. Okumura *et al.*, "Development of a High Brightness Ion Source for the Proton Linear Accelerator (BTA) at JAERI", *ibid.*, pp.645–647

[4] K. Hasegawa *et al.*, "Design Study on an RFQ for the Basic Technology Accelerator in JAERI", *ibid.*, pp.314–316