DESIGN OF A TRANSPORT SYSTEM AFTER THE TIT-RFQ FOR BEAM-PLASMA INTERACTION EXPERIMENTS

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Abstract

A transport system after the TIT-RFQ (an 81 MHz RFQ-Linac at Tokyo Institute of Technology) was designed to suit for beam-plasma interaction experiments. The TIT-RFQ was constructed in 1993 and now has been performing the acceleration test. The transport system consists of three quadrupole magnets and an electrostatic beam kicker. By using this transport focusing system, ion beam of O^+ with currents of 7 mA and an energy of 214 keV/amu will be focused onto a small spot area of about 1 mm^2 at a distance of 2m after acceleration through the TIT-RFQ. The beam kicker is able to kick on the beam less than 100 ns.

This paper will present the arrangement and the design of the transport system for the TIT-RFQ.

Introduction

At Research Laboratory for Nuclear Reactors, TIT, an intense heavy ion linear accelerator system is planned to construct for basic research on Heavy-ion Inertial confinement Fusion (HIF) and a heavy-ion pumped laser [1]. This acceleration system consists of a four vane RFQ linac and an IHQ (Interdigital H structure with RF Quadrupole focusing) linac [2].

The first linac, TIT-RFQ, accelerates particles with a charge to mass ratio (q/A) greater than 1/16 from 5keV/amu up to 214 keV/amu. This RFQ linac was constructed and the first ion acceleration test with He^+ was performed by using a small type 2.45GHz ECR ion source in 1993. An ion acceleration test with C^{2+} was performed in April 1994 [3]. The calculated beam transmission is 91.8% for the beam current of 0mA and 68.4% for 10mA. As the result of acceleration test, transmission efficiency was measured more than 89% with low intensity He^+ beams. The acceleration characteristics agree well with the calculated that. The main parameters of the TIT-RFQ are shown in Table 1.

The 2nd linac, IHQ type accelerator, has been planned a conceptual design study. For this reason, the first experiment to create a heavy-ion induced plasma is intended to carry out only the TIT-RFQ.

TABLE 1
Parameters of the TIT-RFQ

Charge-to-mass ratio	≥1/16
Operating frequency (MHz)	80.9
Input energy (keV/amu)	5
Output energy (keV/amu)	214
Duty factor (%)	10
Calculated Q value	20000
Cavity diameter (cm)	72.5
Cavity length (cm)	425
Normalized emittance (100%) (cm mrad)	0.05π
Transmission (%) Considering the higher order mode	
0mA input	91.8
10mA input	68.4

Design of a transport system

It is necessary for the experiments of a heavy-ion induced plasma that a spot size on the target should be made a minimum to increase a specific deposition power into the target. But, for the TIT-RFQ, it was restricted to arrange the length of a transport system and the efficiency of a final focusing lens because of the limits of a facility and a budget. The transport system was assumed that the length from the tip of a vane to the target is about 2 M and the system was designed that consists of three magnetic quadrupoles, an electrostatic beam kicker, a gate valve and a faraday cup to measure an output beam current for the RFQ.

Beam simulation

The beam dynamics in the TIT-RFQ were analyzed by using the computer code PARMTEQ-H that is a modified version of PARMTEQ [4] and includes effects of higher order harmonics in the intervane potential. The transverse phase-space of an output beam for the TIT-RFQ calculated by the PARMTEQ-H is shown in Fig 1.

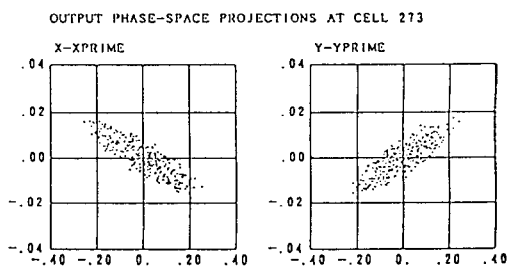


Fig 1. Calculated beam phase-plots at the cell 273 of the TIT-RFQ by the computer code PARMTEQ-H. [O^+ : 10 mA]

The beam envelope for the transport focusing system was calculated by using the computer code MS-TRANSPORT. As the result of the simulation, considering the space-charge effect, a heavy ion beam of O^+ with currents of 7mA is able to be focused onto a spot size of 1.09 mm^2. The calculated beam transport is shown in Fig 2. The each component of this system was designed most adequate by the simulation.

Table 2
Phase-space parameters of O^+ beam at the target calculated by the computer code MS-TRANSPORT.

	Horizontal	Vertical
Xm (mm)	0.27	1.27
Tm (mr)	89.5	19.4

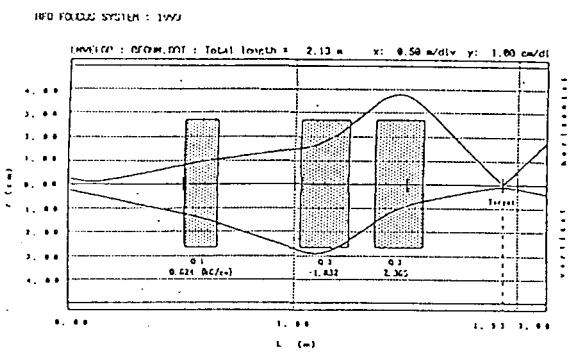


Fig 2. Calculated beam envelope for the transport system by the computer code MS-TRANSPORT. [O^+ : 7 mA]

Focusing magnet

At the design of the magnetic quadrupole (QM2,3), the main parameters, a bore diameter and a maximum magnetic gradient, were assumed that the former is 60 mm and the latter is 3 kG/cm. This is nearly to a magnetic saturation of an iron at the end of the magnetic pole. Parameters of the magnetic quadrupoles made for the transport system are shown in Table 3.

Table 3
Parameters of the magnetic quadrupoles

	QM1	QM2,3
bore diameter (mm)	36	60
core length (mm)	120	180
max field gradient (kG/cm)	2.0	3.0
	(20A)	(30A)

Beam kicker

For the TIT-RFQ, the operating frequency is an 81 MHz and the maximum multiple time of the macropulse is 30 ms and the maximum macropulse width of the beam is 3 ms from the duty factor is 10 %. According to the Q factor (Q ~10,000) of the cavity, the macropulse rise time of the RFQ-beams is about 150 microseconds. For plasma investigations, it is necessary to provide the highest available pulse power onto the target instantaneously for avoiding a preheating of targets. For this reason, the RFQ-beams must be switched on within less than 100 ns synchronizing operating frequency. For this purpose, an electrostatic beam kicker was designed to deflect the beam onto a beam dump during the slow rise time of the macropulse until the maximum beam intensity is reached. The concepts of the TIT-RFQ pulse beam structure are shown in Fig 3. The Kicker is placed between the QM2,3. The applied pulse voltage at this Kicker is 15 kV and the beam of O^+ with 214 keV/amu is able to be deflected about 15 mm at the place of the target.

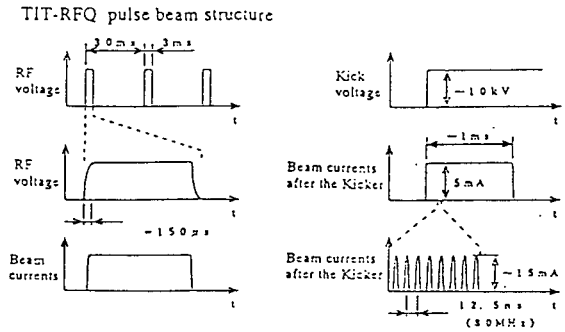
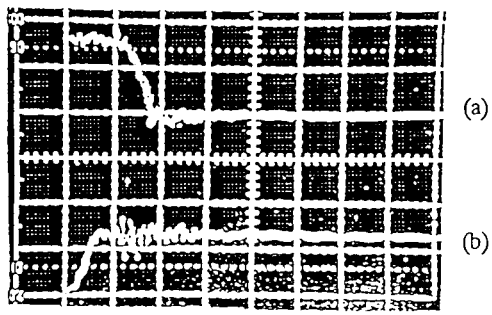


Fig 3. TIT-RFQ pulse beam structure

For the Kicker consist of an electrode in length of 180 mm, a circuit was made that can be generated a deflecting high voltage less than 100 ns. A transition of the voltage between the electrode is shown in Fig 4. TTL pulse can be obtain from the operating frequency.



100 ns/div

Fig 4. (a) Kicker voltage (15 kV)
(b) TTL pulse (5 V)

A layout of the intense heavy ion linear accelerator system at TIT is shown in Fig 5.

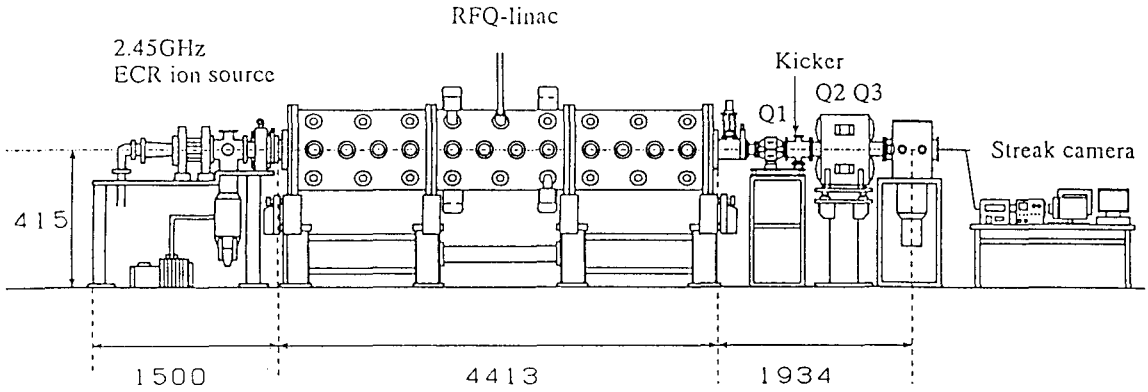


Fig 5 Schematic layout of the intense heavy ion linac system at TIT

Conclusions and Schedule

The transport focusing system was designed for TIT-RFQ. All components had already completed. First experiments to study the heavy-ion-induced plasma is planned to carry out that ion beams focus to a gas puff target. By result of simulations [5], the beam power of 24 kW amounts to a specific deposition power of 15.1 GW/g can be transferred to H_2 gas target (1 atm) using a heavy ion beam of O^+ with currents of 7 mA and an energy of 214 keV/amu. In this case a generating plasma temperature of 1.36 eV is achieved. The plasma parameters such as the electron density and temperature are measured with a CCD camera coupled to a streak camera.

The basic performance test using the ion beam of H^+ with currents of 2 mA will be carried out in September 1994.

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