Study of C 2MeV/u compact Test Linac for Injector of Cancer Therapy

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Abstract

We are studying a heavy-ion IH type linear accelerator for injector of cancer therapy synchrotron. A compact IH linac accelerate C^{4+} ion from 65 keV/u up to 6 MeV/u with APF (Alternating Phase Focus) structure. The linac was designed for practical use. The linac cavity has 3.1 m in length and operation frequency of 100 MHz. A test APF-IH linac was planed in order to demonstrate the acceleration capability. The test linac was design to accelerate C^{4+} ion from 40 keV/u to 2 MeV/u with operation frequency of 100 MHz. From particle orbit calculation, on energy width of ±0.2 %, this linac can accept transverse emittance of 100 πmm mrad, longitudinal phase of 35° and beam intensity of several 100 μA. The test cavity has 1.4 m in length and 56 cm diameter. We made basic and half scale model cavity of this linac and plan to measure its RF characteristics. Using the results of this measurements, conclusive design of this linac will be determined.

1. Introduction

Accelerator complexes for cancer therapy of heavy ion are large facilities.

An injector system of RFQ and Alvarez linac for main synchrotron are large. For popularization of cancer therapy, injector linac complexes are necessary to small. And single linac is best.

An IH (Interdigital H) type linac is used for the basic study. The effective shunt impedance of the structure is five to 10 times higher compared to other acceleration structures [1-4]. Fig.1 show the effective shunt impedance of various types of linac. The study of practical linac for small injector system of cancer therapy was started. We designed IH type linear accelerator with APF whose structure possible to accelerate from low energy. The APF structure can not focus so high intense beam, but beam of several 100 μA is focused by combination of Focus-Defocus sequence (phase-,+). For cancer therapy injector linac, intensity of particles are several 100 μA. Therefore we have a single and compact injector. We designed the IH linear accelerator by particle-orbit calculation. The result is reported as follows.

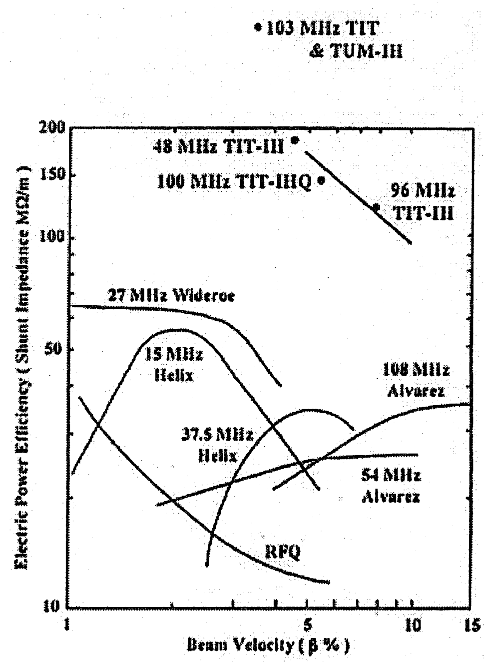

Fig.1 The effective shunt impedance of various type linac.

2. Approach to the compact linac

The merit of IH structure is its power efficiency that is 5-10 times higher than that of other RF linac structure in the low and middle energy range. Therefore, it is possible to generate higher voltages than in other system with the same RF feeding power. In conventional IH-type accelerators, particles are focused in transverse by quadrupole magnets installed in drift tubes or drift tubes with fingertips establish quadrupole electric filed like IHQ linacs[5-8]. Then, if we can avoid quadrupole magnets or fingertips, the. linac will obtain higher acceleration performance of low energy, better power efficiency, simpler structure and advantages for practical use. In the case of ordinal linac, beam intensity is large; beam is defocused with force of space charge effect between particles on the condition of low energy. As the amount of beam current of Carbon ion that is necessary for cancer therapy is sufficient to be several 100 μA, space charge effect gets to have no problem. It was thought that the acceleration with APF having weak focus is available. We examined the acceleration with IH type cavity with APF structure.

Table 1 Main parameters of 6Mev/u C^{4+} APF-IH Linac

Acceleration Particle	C^{4+}
Input Energy	65 keV
Output Energy	6.0 MeV
Operation Frequency	100 MHz
Synchronous Phase	-30°,-30°,30°,30°
Number of Cell	30
Cavity Length	3.1 m
Focusing Sequence	-30°,-30°,30°,30°
Transverse Acceptance	100 π mm mrad
Longitudinal Acceptance	30°
Transmission	~70 % by Buncher
Acceleration Rate	5.9 MV/m

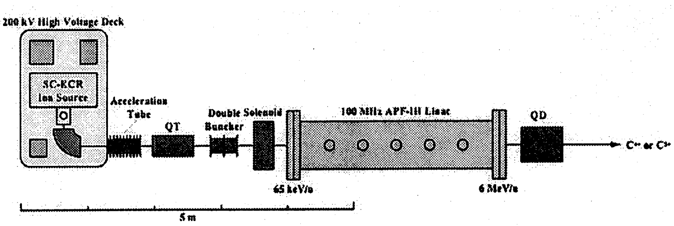

Fig.2 Layout of Carbon 6MeV/u APF-IH Injector Linac for Cancer Therapy

In consequence these are declared that we can accelerate C^{4+} from 65 keV/u to 6.0MeV/u and 40 keV/u to 2.0MeV/u by small and single cavity.

3.Design of compact IH linac

The IH type linac structures are studying at Tokyo Institute of Technology for accelerator of heavy-ion implantation [5-9], accelerator of PIXE and RBS analysis [10] and driver of Heavy Ion Fusion [4,11].

The manner of design is as follows:

1. Particles orbit was calculated various phases using APF by matrix method.
2. Distribution of acceleration voltage was adopted the gradient voltage type whose voltages between drift tubes increase as the energy of particles increases.

A single and small linac that can accelerate C^{4+} from 65keV/u to 6MeV/u was designed. This IH type linac accelerate C^{4+} ion with APF structure. The linac cavity has 3.1 m in length and operation frequency of 100 MHz. Main parameters are shown in table-1. Figure 2 shows designed new APF-IH injector linac system for cancer therapy.

Table 2 Main parameters of 2Mev/u C^{4+} Test APF-IH Linac

Acceleration Particle	p,He,C^{4+}
Input Energy	40 keV/u
Output Energy	2.0 MeV/u
Operation Frequency	100 MHz
Synchronous Phase	-30°,-30°,30°,30°
Number of Cell	22
Cavity Length	1.4 m
Cavity Diameter	56 cm
Focusing Sequence	-30°,-30°,30°,30°
Transverse Acceptance	100 π mm·mrad
Longitudinal Acceptance	35°
Transmission	~70 % by Buncher
Acceleration Voltage/Gap	90-530 kV
Acceleration Rate	4.3 MV/m

A test linac accelerate C^{4+} ion from 40keV/u to 2MeV/u was designed by same method for demonstrate the acceleration capability. According to these calculation, fig.3 shows relation between transverse acceptance and injection energy of Carbon ion with various phase sequence(-,+ and --,++). Figure 4 shows relation between transverse acceptance and injection energy of Carbon ion with various phase (20°,30°,40°) sequence. According to calculation, transverse acceptance is 100 πmm mrad. If normalized emittance of ion source is 0.6 πmm mrad, the beam emmitance is 65 πmm mrad and the linac can accept enough.

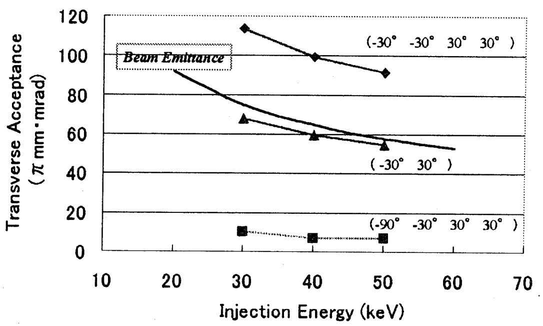

Fig.3 Relation between transverse acceptance and injection energy of Carbon ion with various phase sequence(-,+ and --,++).

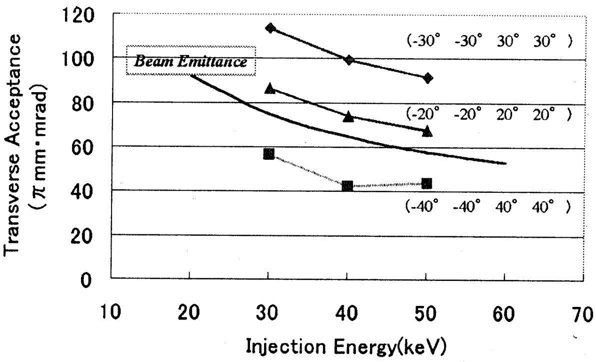

Fig.4 Relation between transverse acceptance and injection energy of Carbon ion with various phase sequence(20°,30°,40°).

The phase acceptance is 35° on energy width of ±0.2% from calculation. And install the bouncer, it is possible to raise enough longitudinal acceptance. Main parameters are shown in table-2. It is supposed that the practical acceleration cavity is 56 cm in diameter and 1.4 m in length. A half scale model cavity being based on results of calculation and measurement of basic model is making now. Figure 5 shows a real scale model cavity of 2MeV/u test APF-IH linac.

4. Conclusion

The IH-APF linac was designed to accelerate C^{4+} from 65keV/u to 6.0MeV for cancer therapy injector. The test APF-IH linac for demonstration was designed to accelerate C^{4+} ion from 40keV/u to 2MeV/u with operation frequency of 100 MHz. It is supposed that the acceleration cavity is 56 cm in diameter, 1.4 m in length. The compact accelerator is very small and energy saving of electric power. The half scale model cavity being based on results of calculation and measurement of basic model is making now. After measuring RF characteristics of the model cavity, real machine will be designed and manufactured.

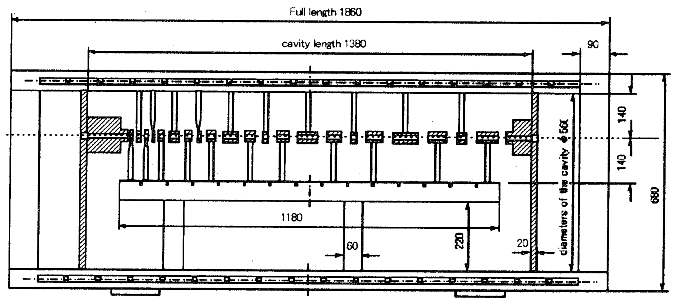

Fig.5 The real model cavity of 2MeV/u Test APF-IH linac

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