THE STUDY OF APF-IH LINAC

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ABSTRACT

We manufactured an IH linac with Alternating Phase Focusing as a new high efficiency cavity for a medical accelerator injector. This linac was designed to accelerate C4+ ions from 40 keV/u up to 2MeV/u. In order to test this linac, a test stand was just assembled which consists of a P.I.G. ion source, bending magnets and focus lenses. The total length of the test stand is less than 5 m including 1.5 m of linac tank length. The operation frequency of the cavity is 100 MHz. In first phase of design process, simple thin lens approximation was adopted. Now we are developing a new beam-tracking code using 3D electro-magnetic simulation software (Micro Wave Studio, High Frequency Structure Solution, OPERA-3D). Using the new code, 3D- beam dynamics including non-linear effects can be easily estimated. We will report linac fabrication, the results of the test and the simulation code development.

INTRODUCTION

A tumor therapy facility using carbons or protons is a typical accelerator application. An injector of HIMAC (Heavy Medical Accelerator in Chiba; Japan) consists of RFQ linac and Alvarez linac accelerate C4+ ions up to 6MeV/u and the length is over 30 m [1].In all designs the layout of the injector linac is an important factor with respect to construction and operation cost as well as to the operation performance of such a medical facility.

We present an Interdigital-H mode structure .with alternating phase focusing (APF) as a new high efficiency cavity for the injector. The IH structure has an advantage of high shunt impedance in low energy region and the technique of APF has been proposed for the design of short low beta structures, because its inherent focusing capability could eliminate the need of external transverse focusing by drift tube quadrupoles [2-5].

The linac which accelerates C4+ ions up to 2MeV/u from 40keV/u with 100MHz is presented.

DESIGN

An initial condition for this linac is that C4+ ion accelerates to 2MeV/u from 40keV/u, an operation frequency is 100MHz, an electric field in a gap is same figure as under twice as Kirpatric and an accelerate ratio is 5 MeV/m. Based on this condition, a length of the linac is 1.5m long, a number of cell was calculated as 22 because of division the length/an average cell length(about 70mm).A total accelerate voltage was divided into cells keeping a constant electric field distribution. Then, we calculated a iteration to find a best phase pattern to work APF by means of a MATRIX code using thin lens approximation and the results are shown in figure1. Next, we calculated 3D electric fields by a 3D-calculater (High Frequency Structure Simulato: H.F.S.S.) to find an end ridge tuner length to get the voltage distribution. The length was calculated as 120 mm.We made a half-scale model to check the distribution by perturbation method; a small Aluminium ball are putted into the gap by a stepping motor controlled by LabVIEW and measured the electric fields by a variation of the frequency. The result shows in figure 3 and the final main parameters are shown in table 1.Based on these parameters, a beam dynamics was calculated.

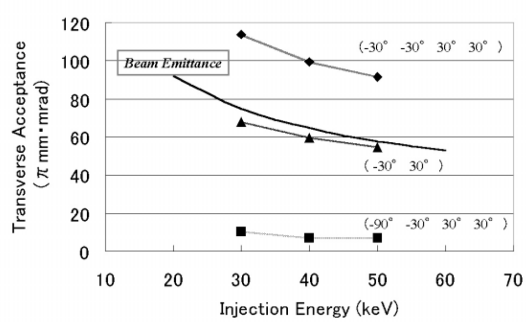

Figure 1: The comparisons of several phase patterns.

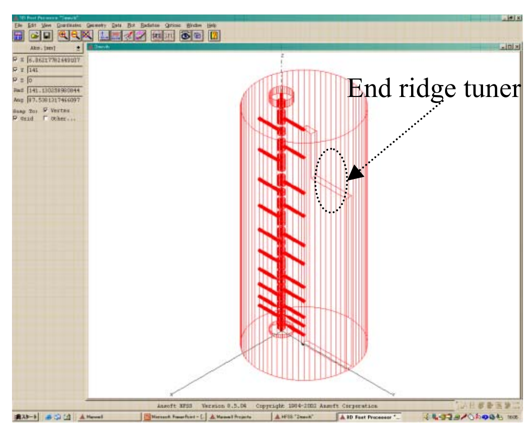

Figure 2: End Ridge tuner length=120mm by H.F.S.S.

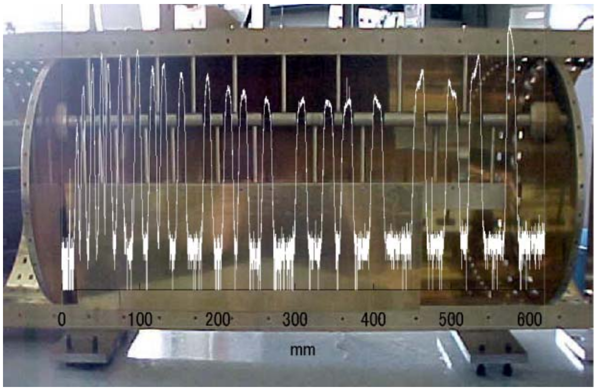

Figure 3: The electric field distribution by model test.

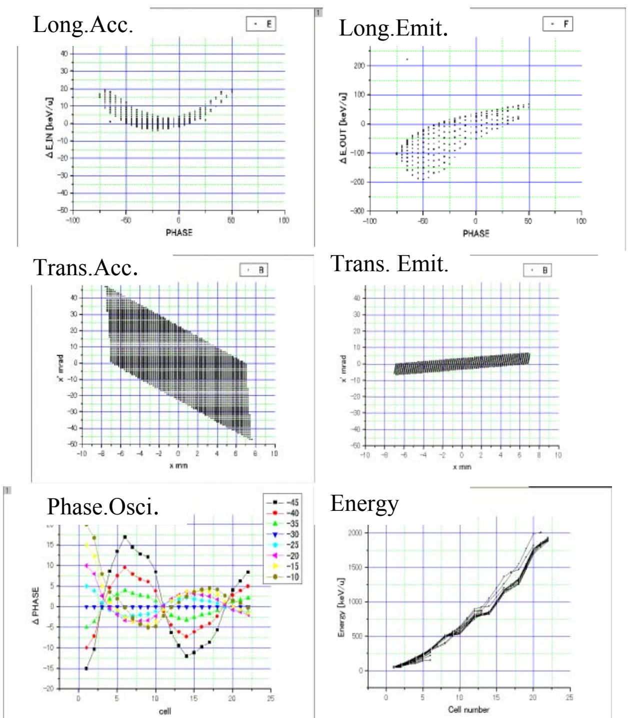

Figure 4: Beam dynamics.

Table 1: Main parameters of the linac

Acceleration Particle	q/A □ 1/3
Input Energy	39 keV/u
Output Energy	1.9 MeV/u
Operation Frequency	97.5 MHz
Synchronous Phase	-30 , -30 ,+30 ,+30
Number of Cell	22
Cavity Length	1280 mm
Diameter of Cavity	φ560 mm
Focusing Sequence	-30 , -30 ,+30 ,+30
Dia. of drift tube	φ38,φ14

MANUFACTURING

The cavity was separated as 3 parts for easily to manufacture and modify drift tubes. The middle plate was manufactured from one stainless plate by NC machining centre under ±0.1mm error. After plating Cu, the drift tubes were aligned and the length of each gap was lined as under ±1%. The top and bottom chambers were also manufactured and checked a vacuum level .After gathering each part, we measured the frequency and the Q-value by a Network Analyzer; the figure showed 97.60MHz and the Q-value is about 10000.

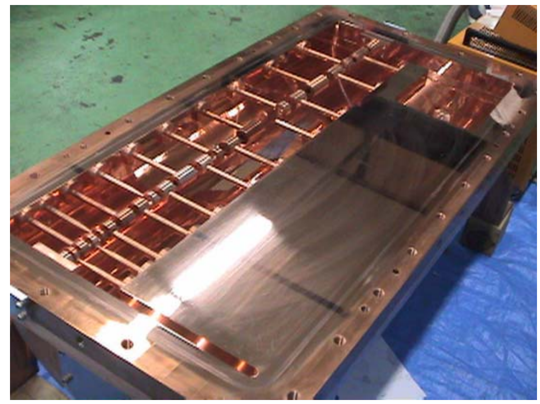

Figure 5: The photograph of the linac.

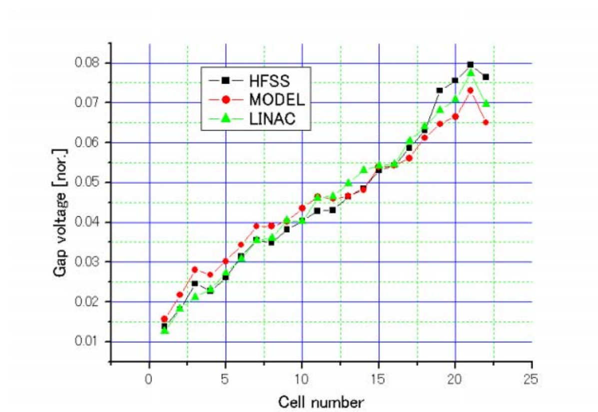

Figure 6: Comparison of the gap voltage distribution.

ACCELERATION TEST SYSTEM

A shunt impedance of the linac is calculated as 215MΩ/m and a RF power will be needed 134kW to accelerate C4+ ions. We have only 30kW power supply, so we will use protons for acceleration test, it will be needed about 15kW.A P.I.G. ion source to make protons was manufactured and measured an emittance using a pepper pot & a multi channel plate (M.C.P.). As a result, the beam emittance was measured as 0.04 mmmrad (nor.).

The acceleration test system consist of the ion source, bending magnet to select only proton, some focusing lenses and another bending magnet to analyze an extraction energy.

Now, We have already aligned all devices under ±0.5mm error and are checking 30kW power supply.

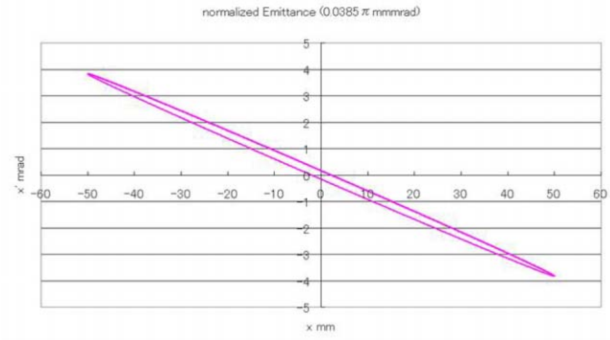

Figure 7: The beam emittance from ion source.

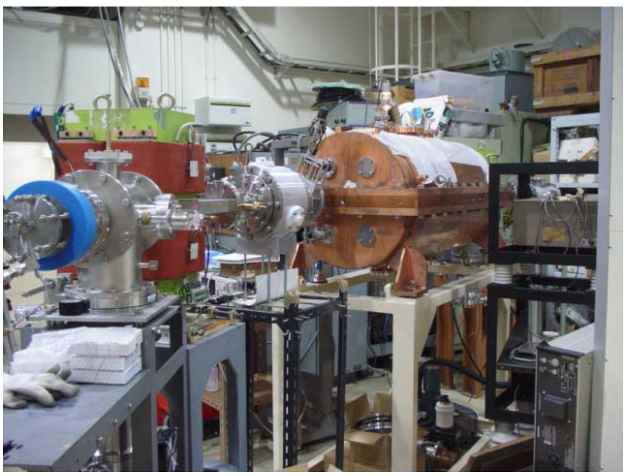

Figure 8: The photograph of all devices to test.

TRACKING CODE

The matrix code which we used is a simple thin lens approximation (the particles are affecting a RF defocusing force at the centre of the gap).The APF depends on this RF defocusing force and this force depends on the position so there are a non-linear effect. We are now making another code to calculate a beam dynamics including non-linear effects. This code is able to calculate particle dynamics on a 3D electric fields by RUNGE-KUTTA and this fields is from a result of one of a 3D electro-magnetic calculator. We demonstrate this code compared with MATRIX code in figure9(x-z beam orbit). The figure shows a advantage of a capability (included non-linear), and a accuracy (3D) to calculate a beam dynamics.

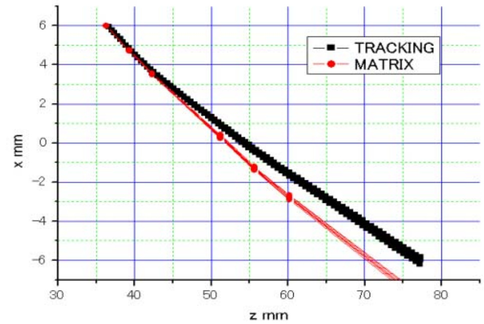

Figure 9: The comparison of TRACKING code to MATRIX.

SUMMARY

We designed and manufactured a new high efficiency cavity for a injector. The beam dynamics were calculated by a thin lens approximation MATRIX code. The structure of the linac was designed by a 3D-calculator (H.F.S.S.) and a ½ scale model. The cavity was manufactured by a NC machining centre and after Cu plating, drift tubes were aligned under ±1% error. Finished to check all devices for acceleration test with protons and alignment was done under ±0.5mm error. Otherwise, we are making a new code to calculate beam dynamics including a non-linear effect. For an APF structure, it is an advantage to know beam dynamics including the effect.

We will do the acceleration test and finish to make the new code and demonstrate the new efficiency cavity by the test, the MATRIX code and the TRACKING code.

REFERENCES

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