ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-TUPO101

DESIGN OF PRACTICAL HSC TYPE INJECTOR FOR CANCER THERAPY

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Abstract

We provided a compact linac injector, HSC (Hybrid single cavity), for cancer therapy. The HSC, operated in TE_{111} mode [1], consists of RFQ section and DTL section. This compact linac injector, running in frequency of 100 MHz, accelerates C^{6+} beams with 20 mA from 20keV/u up to 4 MeV/u [2]. The total length of HSC is designed less than 4 meters. We used RGQGen and PIMLOC to achieve the aims. More details will be given in the next parts.

INTRODUCTION

According to investigations, there are 6 people per minute suffering from cancer in china. Therefore, accelerators in medical applications have a great prospect. Unfortunately, the system of cancer therapy has a complex control system and huge injector. The factor resists the developments of accelerators in medical applications. The new type injector, HSC, has the ability to directly accelerate the high intensity C^{6+} ion beams. Compared with traditional types, HSC adopts DPIS (direct plasma injection scheme), which could easily supply enough C^{6+}ions to the linac. Secondly, RFQ section and DTL section share the operating system and feed system.

BEAM DYNAMICS

RFQ Design and DT Design

The section of RFQ, 4 rod IH type, was designed to accelerate C^{6+}ions to 0.6 MeV/u from 0.02 MeV/u. This RFQ section includes 90 cells. And the total length of RFQ is 1050 mm. The main parameters are listed in Fig. 1 and Table 1. Fig .2 gives the transmission efficiency, which almost over 95%, at last cell.

Table 1: The Main Parameters of the RFQ

Parameters	Value
Voltage	85 kV
B	7.1→9.76
m	1→2.11
ϕ	-90→-26 deg
Input energy	0.02 MeV/u
Output energy	0.6 MeV/u

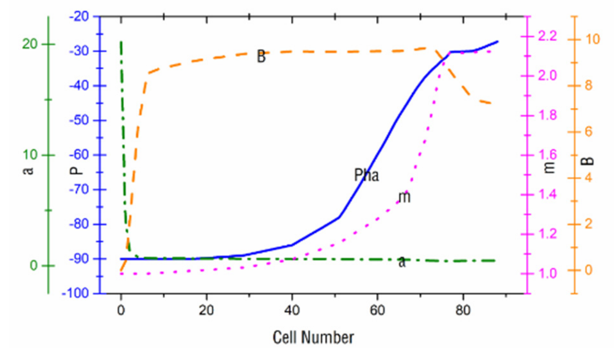

Figure 1: The dynamics parameters of RFQ design.

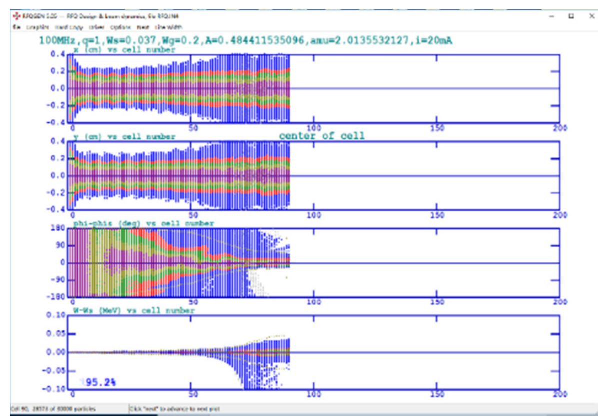

Figure 2: Transmission efficiency at last cell.

The output of RFQ are adopted convergent design for following DT injection. Therefore, the section of DT accelerates C^{6+}ions with 20 mA to 4 MeV/u from 0.6MeV/u. We used the PIMLOC to design the DT section. The most important theory in DT section is APF, Alternative Phase Focus. An APF linac is a modified version of usual drift tube linacs (DTL) and can achieve three-dimensional focusing without the installation of quadrupole lenses into the drift tubes. The phase in each gap was given in Fig. 3.

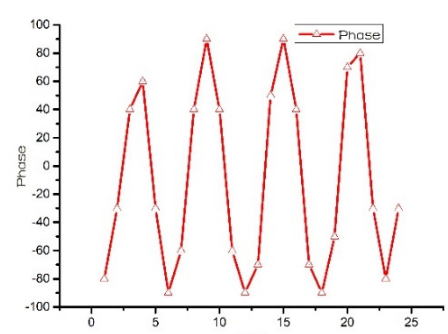

Figure 3: The phase in each gap.

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The more parameters, length of DT and Gap, were showed in Table 2.

Table 2: Main Parameters of DT Design for HSC Linac

Parameters	Value
Voltage	211 kV
Cell number	24
Length	1753 mm
Bore radius	13 mm
DT radius	30 mm
Phase injection	-112 deg
Input energy	0.6 MeV/u
Output energy	4 MeV/u

The number of particles is 10000. Tracing the particles, we could get the results of simulations. Figure 4 gives the transformation of beam envelope. The output at the end was gives in Fig. 5. Transmission efficiency is over 99%. But the acceleration efficiency is only 30%.

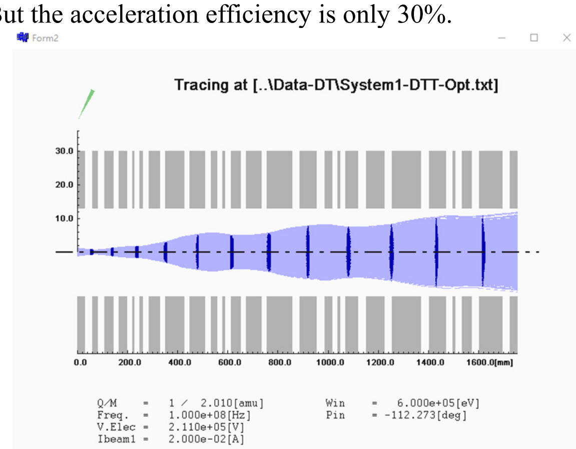

Figure 4: Beam envelope at z axis.

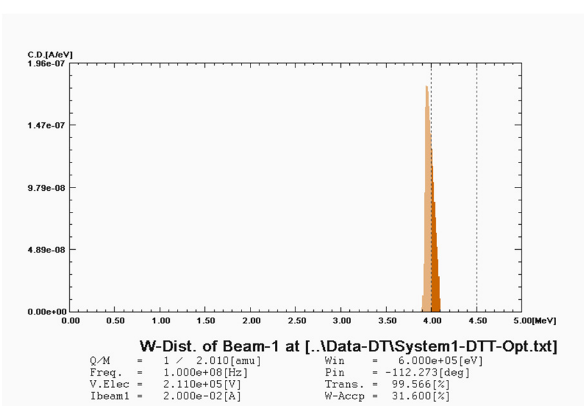

Figure 5: The energy distribution.

HSC Linac Basic Feature

Next, we used the PIMLOC to simulate the whole structure, both RFQ and DTL. The number of particles in HSC is 10000.We can change the length between RFQ and DTL, L RFQ-DTL, to get the results at the end. Table 3 gives the parameters in HSC. And Fig. 6 gives the distribution of electromagnetic fields between RFQ and DTL.

Table 3: The Parameters in HSC

Parameters	Value
Total length	3019 mm
L RFQ-DTL	59 mm
Rcavity(DTL)	280 mm
Rcavity(RFQ)	95 mm

Ordinarily, a MEBT was inserted between RFQ and DTL. On the contrary, the initial HSC model was only combined RFQ structure and DT structure.

According to results, shown as Fig. 6, we can know that the E field is focused in the connection parts of 4-rod and first DT. Beam in gap of rod and 1st DT will be subjected to strong accelerating force, and it should be considered that discharge could be led to high voltage and beam acceleration could be received negative influence by unbalance electric distribution.

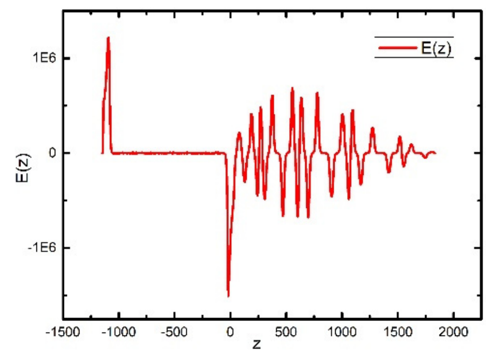

Figure 6: The distribution of E field along the beam direction.

Capacitance in RFQ part is much stronger than DT part. So we could consider that C in whole HSC linac is focused in RFQ section [3]. Therefore, RFQ section shows sensitive in the E field distribution.

For reducing this concentrated E field distribution, interface structure had been designed and discussed. Fig. 7 gives the outline of interface structure and E-field distribution in the different length of interface.

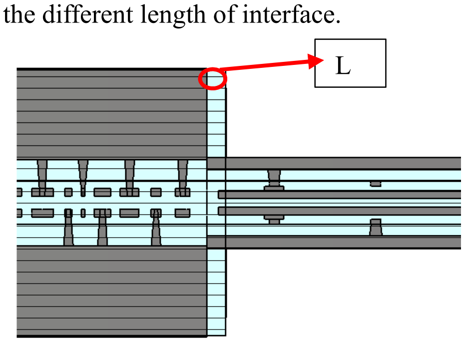

Figure 7: The interface structure and E-field.

When we change the length of L, as the Fig. 8 shown, we can modify the E-field between RFQ and DTL.

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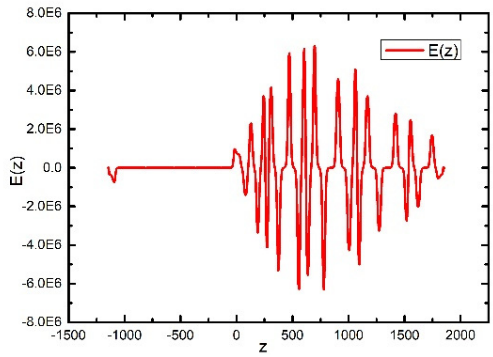
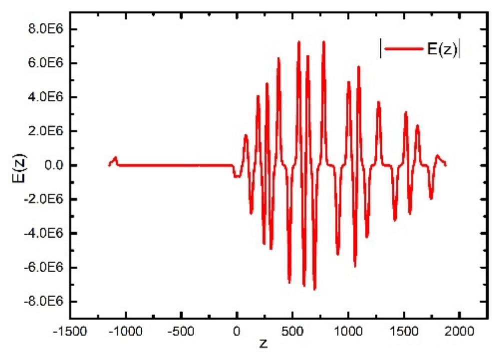


(a)



(b)

Figure 8: (a) L=20, (b) L=40 and the axis E field distributions simulated by MW-S.

SUMMARIES AND FUTURE PLAN

We have studied a new HSC type linac which is a practical and efficient machine to accelerate high intense ion beam. We discussed the E matching designs for reducing the concentrated electric field distribution and investigated relation of meth and power & frequency.

In the next step, we will study multi-physical fields of HSC by ANSYS. The acceleration test will be operated in this November.

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