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Particle Orbit Simulation for High Energy Heavy Ion Implanter

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1. Abstract

We have studied an Interdigital-H type Quadrupole (IHQ) linac structure for application to heavy ion implanter. It is possible to vary the output energy by changing the voltage between gaps only. Operating frequency of this IHQ linac is 30 MHz and the synchronous phase is -30°} with the exception of -90°} at the first gap that works as a bunching section. The calculated results show that the output energy can be varied from 0.48 MeV (30 keV/u) to 1.6 MeV (100 keV/u) for $^{16}O^{+}$.

2. Introduction

The Heavy ion accelerator technology has been expected to be used in the industrial fields. Conventionally, electrostatic accelerators and cyclotron have been used in those fields. Heavy ion linear accelerators, however, gradually have been developed and used in those industrial applications. In particular, radio frequency quadrupole (RFQ) linacs have been developed and adopted for ion implantation in recent years [1), 2)]. However, An RFQ has a problem for low acceleration rate. To solve this problem, we used an IHQ linac that is better than other kinds of linac for acceleration rate. This linac has the drift tube with finger tips to focus the particles, and can vary the output energy so as to be suitable for industrial applications.

Normally drift tube linac is not suitable for variable energy accelerator, because cell length is not appropriate for particles when the gap voltage is changed. Therefore the particle is lost gradually, and it is not able to vary the output energy if there are many cells in the cavity. For the linac we have developed, particles can pass through all drift tubes without many particle losses because of small gap numbers. Consequently, this linac accelerates the particles with variable output energy.

This paper presents the calculated results of beam simulation.

3. Calculation and results

Table 1 shows the principal parameters for IHQ linac.

Table 1 Basic parameters for calculation

Charge to Mass Ratio [q/A]	≥1/16
Operating Frequency [MHz]	30
Input Energy [keV/u]	15
Output Energy [keV/u]	30 (Min.) 100 (Max.)
Synchronous Phase [deg.]	-90→-30
Maximum Gap Voltage [kV]	214
Number of Cell	10

This linac accelerates the particles from 0.24 MeV to 1.6 MeV (maximum) for $^{16}O^{+}$. There are 10 cells in the tank and the length needed to accelerate is 0.53 m, but the cavity length is 1.04 m as the electric quadrupole lens is mounted in the cavity. Therefore, acceleration ratio is 1.31 MV/m (2.57 MV/m for only acceleration section). The operating frequency is 30 MHz and synchronous phase is -90° at the first gap and -30° at the other gaps.

By using these parameters, the calculation was done the thin lens approximation. Fig. 1 shows the output energy distribution with different values of gap voltage. V is the normalized gap voltage (1.0 is the designed value) and E is the output energy. It was shown that the total output energy can be changed from 0.48 MeV to 1.6 MeV.

Fig. 2 shows the transmission as a function of gap voltage. The transmission for the drift tube with finger tips is better than the other at the high energy region. Therefore focusing with the finger tips is effective for high gap voltage. On the other hand, for the low gap voltage, no - finger - type is superior to the other because the particle is not lost so that the rf defocusing may be weak if the force due to the finger is not added. However, as the transmission is good, it is not so problem for using the beam practically.

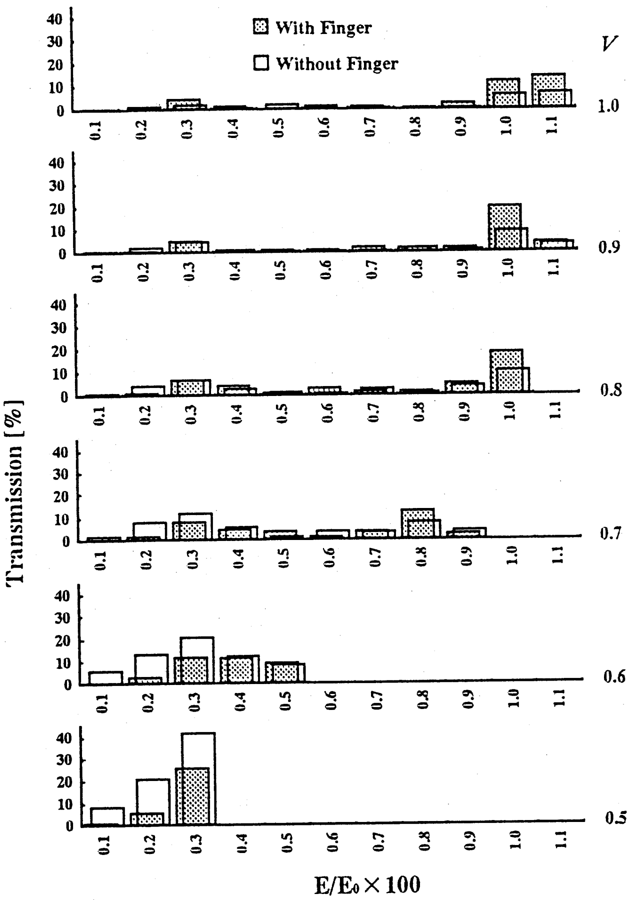

Fig. 1. Output energy distributions at various gap voltages. V is the normalized voltage and E_0 is the designed output energy (100 keV/u).

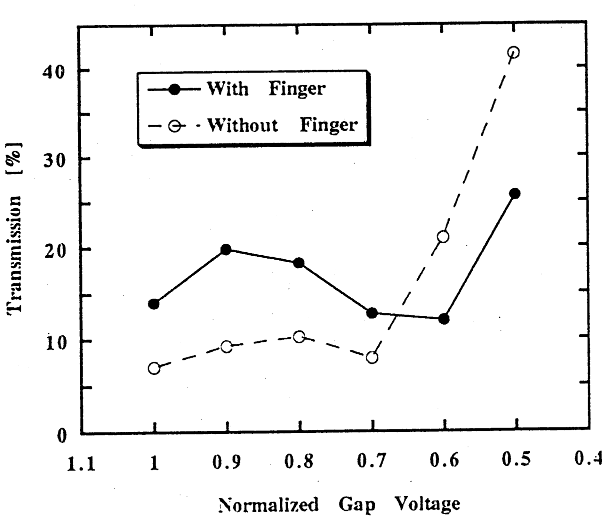

Fig. 2. Transmission with different gap voltage

4. Conclusion

A new drift tube linac that can vary the out put energy by changing only gap voltage was presented. This accelerator is suitable for the industrial application because of the advantage of high acceleration rate (1.31 MV/m). The calculation of beam dynamics shows the following results:

- The out put energy can be varied from 0.48 MeV (30 keV/u) to 1.6 MeV (100 keV/u) for $^{16}O^{+}$.
- The electric quadrupole field made by finger tips is effective at high gap voltage.
- The cavity length (with the sections that electric quadrupole magnets are mounted) is 1.04 m because of the high acceleration rate.

5. References

1) Schempp and H. Deitinghoff, Nucl. Instr. and Meth. B68 (1992) 36.

2) Robert W. Hamm, Nucl. Instr. and Meth. B68 (1992) 1.