A CHANGE OF RESONANT FREQUENCY OF IH-LINAC FOR RADIOACTIVE NUCLEAR BEAMS

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Abstract

We have performed a study to change resonant frequency of a 51MHz interdigital-H linac for accelerating radioactive nuclear beams. As a method to change the frequency, we adopt the way of increasing the drift tube length. Rf measurements by cold models have been performed. Their results are compared with MAFIA simulations.

1 INTRODUCTION

The heavy ion linac complex which comprises a 25.5MHz RFQ and a 51MHz IH-linac had been used for accelerating radioactive nuclear(RN) beams up to 1.05 MeV/u at KEK-Tanashi campus[1]. The first acceleration of RN beams was accomplished in 1997[2]. These linacs will be moved to the tandem facility at JAERI-Tokai, and will be connected to an existing super conducting(SC) linac in order to accelerate the RN beams up to the energy region beyond the Coulomb barrier. For achieving this scheme, an additional IH-linac(IH2) is required to boast up to the acceptable beam energy. Since the existing-super conducting linac has a resonant frequency of 129.8MHz, that of the IH-linac is changed from 51.0 MHz to 51.92MHz. As a method to change the frequency, we adopt the way of increasing the gap length. Rf measurements to determine drift tube length have been performed by using cold models and compared with the results of the MAFIA simulations.

2 HOW TO CHANGE THE FREQUENCY

Since the resonant frequency is inversely proportional to $(LC)^{1/2}$, therefore, we can increase the frequency by decreasing the capacitance or inductance of cavities. A way to reduce the inductance makes the shunt impedance worse. A way to reduce the capacitance is better. There are two ways to reduce capacitance between drift tubes, first is to reduce the outer radius of drift tubes and second is to shorten drift tube length. The former has a mechanical problem to connect the drift tubes with the stems, since the drift tubes are rather thin. Therefore, we have chosen the latter way. Original parameters of the IH linac are listed in Table 1. We increase the gap length listed in this table by shortening the drift tube length. For the end drift tubes fixed at the end plates, original ones are used with no modification, since cost to replace them with complicated shapes is expected to be high.

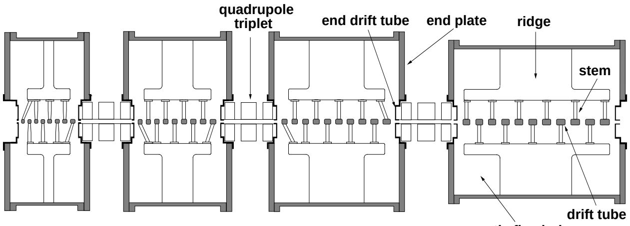

Figure 1: The structure of IH-linac

Table 1: Original design parameters of IH-Linac

	Tank1	Tank2	Tank3	Tank4
Cavity length(m)	680.6	901.0	1156.4	1536.3
Cavity radius(mm)	744.5	744.5	744.5	670
Gap length(mm)	29	37	45	53
Cell number	9	10	11	12
Drift tube inner radius (mm)	10	12	14	16
Drift tube outer radius (mm)	19	22	23	26

3 CALCULATION

To determine the dimensions of the drift tubes used in the cold model tests, the three-dimensional calculations are performed by a computer code MAFIA. We calculate the resonant frequencies by using several gap lengths of the drift-tubes in each tank, and find the relation between the resonant frequency and the gap length. From this relation, we expect a gap length, which gives a goal frequency. The drift tubes with this expected gap length are used in the model test, and it is verified experimentally if the measured resonant frequency agrees with a goal one. Pentium 4 computer with the 2GHz clock and memory 1.5GB is used for the calculations. Typical CPU-time is ~3 hours/Job. Mesh size is more than two

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millions. Fig 2 shows a material plot for the Tank 3 cavity. The mesh lines are manually set, and made dense around the ridges and drift tubes. Although the tips of the drift tube are round in practice, they are approximated to be flat in the calculations. Since the capacitance between drift-tubes is calculated to be larger a little bit, we can expect that the calculated resonant frequency is lower than the measured one.

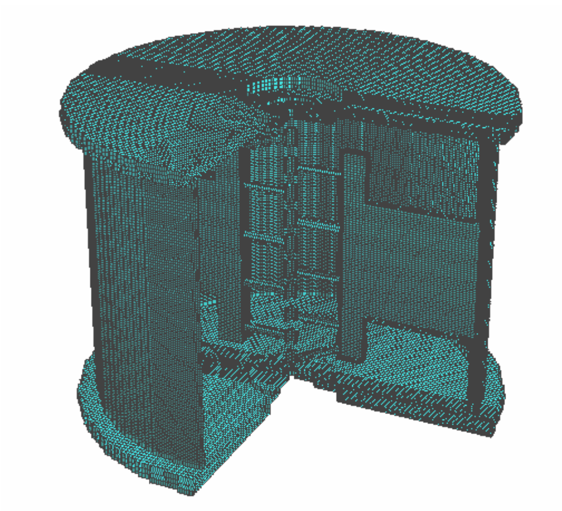


Fig 2: Material plot of Tank3 for calculation.

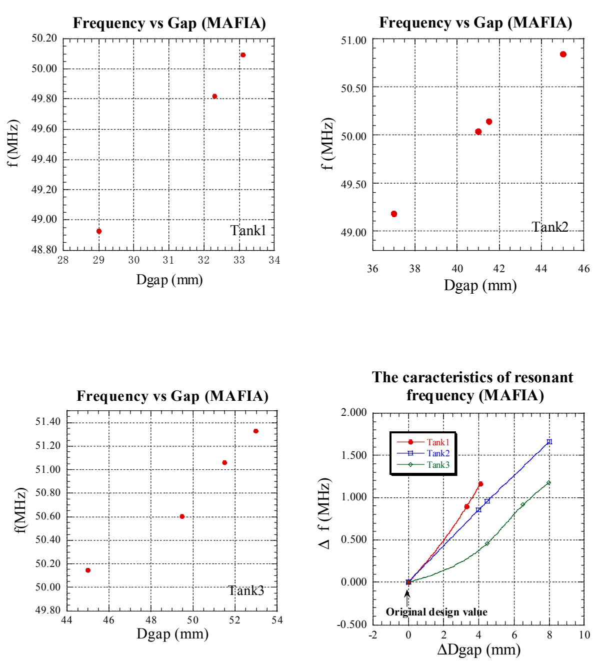
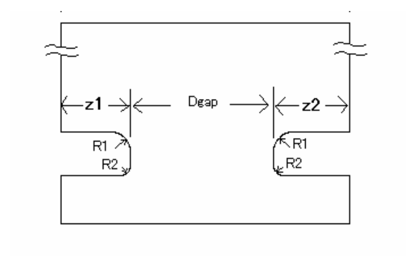


Fig 3:The calculation result.

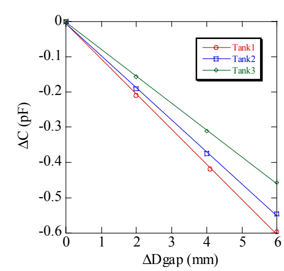
In order to obtain the relation between the capacitance change ΔC and gap-length one $\Delta Dgap$, the capacitances of three tanks were calculated by using a two-dimensional calculation code POISSON. The capacitance was obtained from a stored energy. Fig 4 a) shows a cross section of drift tube per cell, and the capacitance change expressed as a function of the gap-length one. As seen in Fig 4 b), the slope of capacitance change is most steep for tank 1. Therefore, We can understand qualitatively that the frequency of the tank 1 changes most large among three tanks when the gap lengths of the three tanks are changed by the same length $\Delta Dgap$ (see Fig 4).

Table 2: Parameter for 2D-calculation

	Tank1	Tank2	Tank3
Z1(mm)	14.18	19.04	25.00
Z2(mm)	15.37	20.22	26.18
R1 (mm)	4	4	6
R2 (mm)	2	2	2



a)



b)

Fig 4:a) Cross section of the drift tube per a cell, and b) the calculation result of capacitance

4 MEASUREMENT

Each cavity of the IH-Linac has a capacitive tuner and a inductive tuner. The variable range is covered within 100~150 kHz. Therefore, we must set the frequency to the goal one with an error within ~50kHz (0.1%). Models of the IH-linac are used to determine the length of drift tube. Fig5 shows a photograph of the model cavity. A reduced scale of the models is 1/2.222 compared with the actual cavities. The material of the models is brass. The drift tube and stem are soldered together. When they are fixed to the ridge, the gap length is adjusted with an accuracy better than 0.1 mm by putting a cylinder with an accurate length between drift tubes, and a rod with an accurate diameter is inserted into all drift tubes to align the drift tubes precisely. The measurement system comprises a vector volt meter, HP8508A, and a signal generator, HP8644A. They are connected to the PC via GPIB interface, and controlled by a program written by Visual Basic6.0. The field measurements are carried out by the bead pull method. The perturbing bead is a sphere made of aluminium. The field is disturbed if size of the bead is too large, and the signal is not detected if it's too small. Then, as a preferable bead, a sphere of 1/8 inch in diameter has been chosen. The bead is moved at 1.3 mm increment along the longitudinal axis. The interval for measurement is set to be one second. Fig 6 shows the measurement results of the electric field and the gap

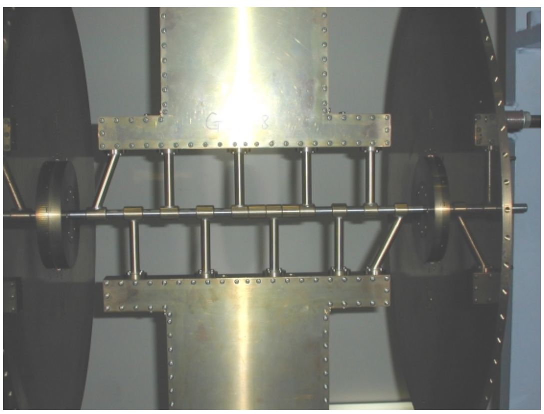
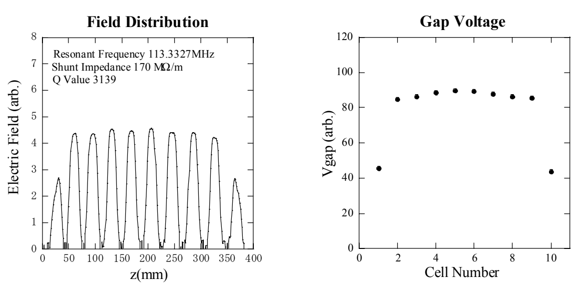
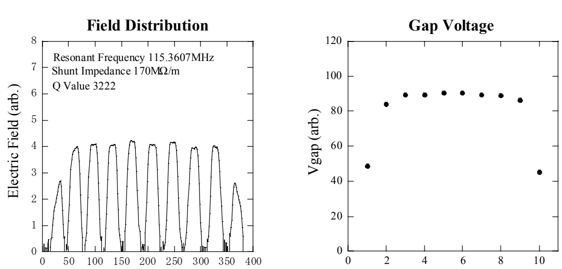


Fig 5. Photograph of a model cavity.



a) Before exchanging the drift tubes



b) After exchanging the drift tube

Fig 6. Field distribution and gap voltage before and after exchanging the drift tubes.

voltage in Tank2. The flatness of the gap voltage is almost same before and after exchanging the drift tubes. The shunt impedance dose not change. The measured values of the resonant frequency are shown in Fig 7. The measurement results agree with the simulations by MAFIA. As for tank 2, the required frequency has been successfully obtained with an error less than 0.1%. The measurement results give the moderate curves expressed as a function of the gap length. Therefore, the gap lengths corresponding to a goal frequency can be easily obtained from these curves.

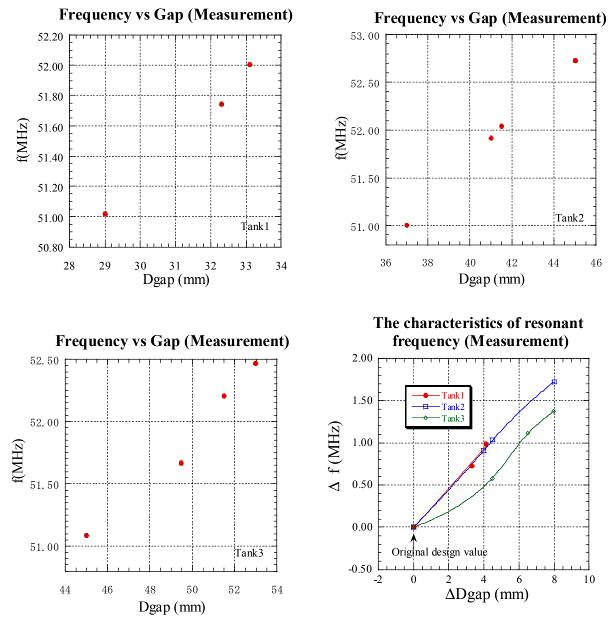


Fig 7. Measurement results

5 CONCLUSION

The relation between the resonant frequency and the drift tube gap length has been obtained by means of model tests and simulations. The both results agree well with each other. The drift tube dimensions of the tank 1 to 3 of the 51.92-MHz IH linac are estimated from the above results. In near future, the same studies will be performed for the tank 4, and the drift tube dimensions for 51.92-MHz estimated in a similar way.

6 ACKNOWLEDGEMENT

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7 REFERENCES

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[2] M. Tomizawa. et al, "ACCELERATION TEST OF RADIOACTIVE NUCLEAR BEAM AT INS," PAC'97,