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TUNING AND LOW POWER TEST OF THE 325 MHz IH-DTL AT TSINGHUA UNIVERSITY

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Abstract

An interdigital H-mode drift tube linac (IH-DTL), which accelerates proton beam from 3 MeV to 7 MeV has been designed and assembled at Tsinghua University. There are 8 plungers in the 1 m tank and one coaxial coupler is used to feed the power. The frequency is tuned to 325 MHz. The field distribution is measured by the bead perturbation method. Finally, the gap voltage error has been tuned to be within ±3.0%, which satisfies the design requirement. The Q factor of the tank is 7000 while the power dissipation is 244 kW. Details of the low power test is presented.

INTRODUCTION

Since 1950s, IH DTL was firstly proposed by J.P. Blewett, it has been carefully studied and been adopted as the heavy ion accelerators. Because of its high shunt impedance and high accelerating field, IH DTL is adopted widely for the injection of the synchrotron-based medical facilities [1-3]. A 325 MHz IH DTL has been designed, fabricated and assembled at Tsinghua University for the medical purpose [4,5]. The length of the IH DTL is about 1 m and the 3 MeV proton from the RFQ can be accelerated to 7 MeV. A modified KONUS beam dynamics has been adopted in the design [5]. There are no magnets in the tank. The RF characteristics has been studied with the 3D microwave studio. The Q_0 factor is 11300 and the power dissipation is 151 kW. The designed parameters of the IH DTL are listed in Table. 1.

The tuning method of the IH DTL has been carefully studied. Several kinds of the IH tank has been tuned and reported [2,3,6]. The relative error between the measurement and the design is within ±3% mostly. For the 325 MHz IH DTL, 8 symmetric plungers are adopted for the tuning. The tuning range of the frequency is about 10 MHz. After the error analysis of the beam dynamics, the requirement of the error between the measurement and the design is≤±3.0%, which is consistent with the other IH DTLs. Details of the low power test and the tuning will be presented.

Table 1: Parameters of the IH-DTL

Parameters	**Value**
Particle species	Proton
Frequency	325 MHz
Injection energy	3 MeV
Output energy	7 MeV
Tank length	1.14 m
Number of cells	21
Frequency	325 MHz
Q_0	11300
Power	151 kW
Z [MΩ/m]	193 MΩ/m
ZTT×cos$^2(\phi)$ [MΩ/m]	107 MΩ/m
E_{peak}	2.3 Kp

LOW POWER TEST PLATFORM

The low power test plat form is composed of a stepped motor with the controller, a vector network analyser, and a co-axial coupler. The electric field is much smaller at the both ends of the tank while the magnetic field is much bigger. Thus, an insulated bead is adopted for the bead perturbation measurement [7]. The bead is pulled by the stepped motor with constant velocity and S21 signal of the VNA is used to measure the phase variation.

The low power test has been divided into two stages. The first stage of low power test is performed at Tsinghua University before the paint. The frequency is tuned to 325 MHz and the relative gap voltage error is within ±3.0% with the adjustable aluminium plungers. The high power operation will be performed at site where is one thousand kilometres far from Tsinghua University. The performance of the tank is worried after the long-distance transportation, therefore the second low power test is performed. Figure 1 shows the platform at both sites. There is no difference between the two measurement. Thus, the result shows that the long-distance transportation causes little influence on the tank.

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Figure 1: The low power test platform of the IH DTL (up: Tsinghua University, down: NIST).

TUNING WITH THE ALUMINIUM PLUNGER TUNERS

There are two kinds of tuners for the IH DTL tuning: the movable aluminium plunger tuners and the fixed-length copper tuners, shown in Fig. 2. The tank of the IH DTL is tapered to adjust the electric field on the axis. The depth of the tuners is defined as the distance from the tuner to the axis. At the beginning, the aluminium tuners are inserted to the design position. Due to the fabrication and assembly error, the resonant frequency is 321.8 MHz while the simulation result is 324.9 MHz. There is a 3.1 MHz offset between the real tank and the simulation model. From the design position, all the tuners are moved the same distance. Then, the measured frequency is consistent with the simulation result if the offset is considered, exhibited in Fig. 3. Thus, the tuning range of the eight tuners is about 10 MHz. After changing the depth of each tuner, the frequency of the tank is tuned to 324.9 MHz under atmospheric pressure, which is corresponding to the 325 MHz under the working situation. Meanwhile, the electric field is tuned to the design.

Figure 2: Two kinds of tuners (left: aluminium plunger tuner, right: copper tuner).

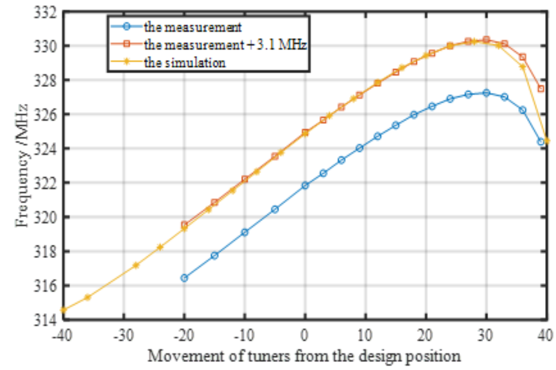

Figure 3: The tuning range of the tuners.

The stepped motor is not triggered by the VNA trigger signal. Thus, the start and end of the measured phase data of S21 are not related to the movement of the insulated bead. There is some random noise of the phase in the measurement as well. A detailed data processing is necessary. The flowchart of the data processing is shown in Fig. 4. Firstly, the peak points of the measured phase for different cells is found. A parabolic fitting of the data near peaks is used to get the more accurate position of the peaks. Then the measured peak points are fitted to the simulated peak points to get the relationship between the measured data and the simulated data. Next, a low pass filter is adopted to decrease the random noise. The baseline of the measurement is varying during the measurement. The baseline error is decreased by minus the broken line composed by the zero points (the zero points is the minimum points between the neighbouring two cells). Then, the square root of the phase shift is proportional to the electric field on the axis. The voltage of each cell is the integral of the electric field. Fig. 5 shows the electric field distribution and the cell voltage distribution. The depth of each aluminium tuner is changed to tune the frequency as well as the field distribution of the tank. The final error of the field distribution and voltage is $\leqslant \pm 3.0\%$. The quality factor of the tank is 5600 with the aluminium tuners.

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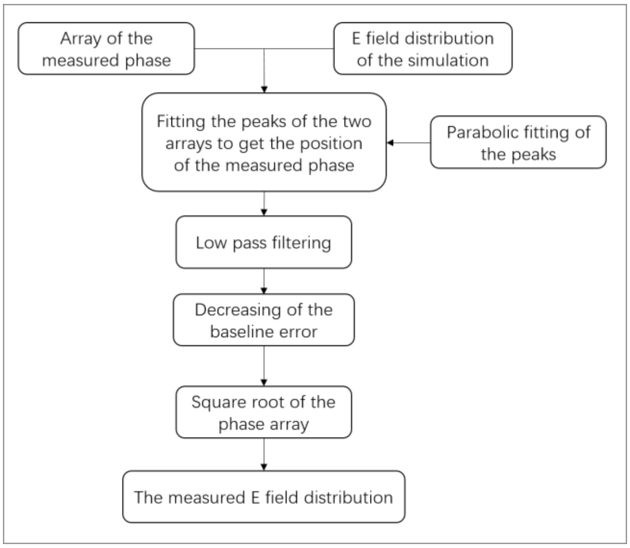

Figure 4: Flowchart of the data processing.

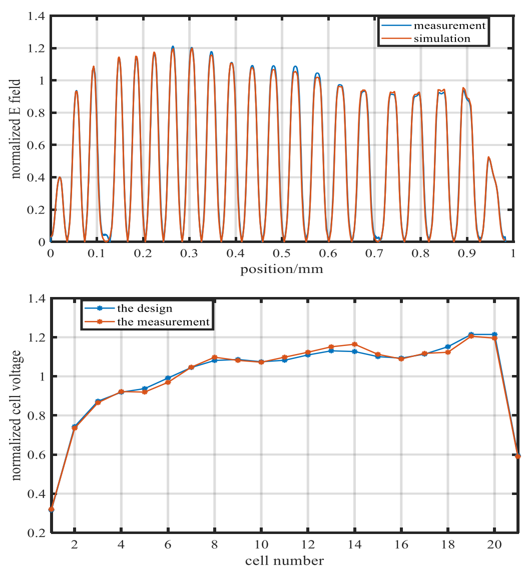

Figure 5: The electric field distribution and cell voltage of the IH DTL tank.

RESULTS WITH COPPER TUNERS

After tuning the IH DTL, the aluminium tuners are replaced by the copper tuners. Thus, the tank can be operated with the high power in the future. The C rings and O rings are adopted to seal the RF and the vacuum separately. Finally, the quality factor of the tank is about 7000 and the frequency remains to be 324.9 MHz. Ten times of the bead perturbation method are adopted to estimate the random noise of the measurement. The results are exhibited in Fig. 6. The random error of the measurement is bigger at the first cell and the last cell where the electric field is much smaller than the others. The random error of all cells is $\leq \pm 0.5\%$ and $\leq \pm 2.0\%$ for the peaks and the cell voltage separately, exhibited in Fig. 7. The difference of the measured electric field and the design is $\leq \pm 3.0\%$, which satisfies the design requirement.

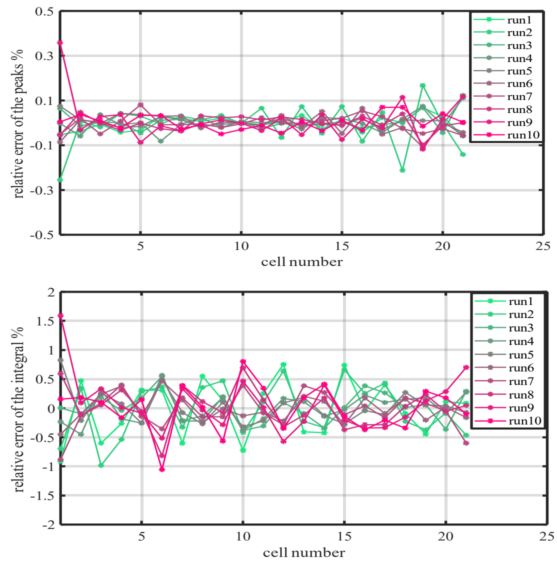

Figure 6: Repeatability of the measurement (up: peaks, down: cell voltage).

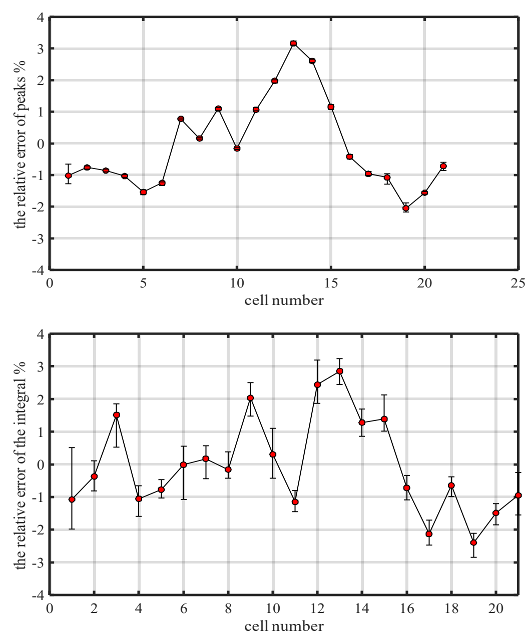

Figure 7: Relative error of the measurement with copper tuners and the design.

CONCLUSION

The fabrication and assembly of the 325 MHz IH DTL have been done at Tsinghua University. The tuning and low power test have been finished. A bead perturbation method is adopted to measure the electric field distribution on the axis. The relative error between the measurement and the design is smaller than ±3.0% in most of the cells which satisfies the design requirement. The Q_0 of the tank is 7000 and the corresponding power dissipation is 244 kW.

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