TEST SCHEME SETUP FOR THE PEFP 20 MeV DTL*

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Abstract

A 100 MeV proton accelerator is under development for the Proton Engineering Frontier Project (PEFP). The goal of the first stage of the project is to develop a 20MeV accelerator and the initial test of the 20 MeV accelerator will be made. The DTL of 20 MeV accelerator consists of four tanks and will be driven with single klystron, which gives rise to some unique problems with regard to the way of independent resonance control for each tank. Some changes made in the LLRF for reducing phase or amplitude error of cavities affect all of four tanks simultaneously, for which it is not possible to use LLRF for individual control of phase and amplitude of each tank. For independent control of each tank, we are going to use the temperature control of the drift tubes as a frequency tuner. During the initial test of the DTL, the phase of each tank will be synchronized with the first tank phase, and beam based test will be performed as if all of tanks were single unit. The detailed description of the test scheme and the analysis results will be given in this paper.

INTRODUCTION

The 100 MeV proton accelerator is under development for the Proton Engineering Frontier Project [1][2]. For the first phase of the project, the construction of 20 MeV accelerator which consists of the ion source, LEBT, RFQ and DTL is near completion. The overall system and the DTL tanks are shown in figure 1 and 2, respectively.

The conventional type 20 MeV DTL is composed of 4 tanks and driven by single RF source in contrast with the usual way of RF feeding to the DTL tanks where there are as many number of RF sources as that of DTL tanks.

Figure 1: Overall system of PEFP 20 MeV accelerator.

Figure 2: PEFP DTL with subsystem.

To drive all of 4 tanks with single RF source, the RF power from the 1 MW klystron is split into 4 ways using magic T [3]. The RF system has phase shifter with three stub tuners in each waveguide leg which can be adjusted only manually. The phase shifter can be used for compensating the initial phase difference between each tank. The schematic layout of RF delivery system of 20 MeV DTL can be seen in figure 3.

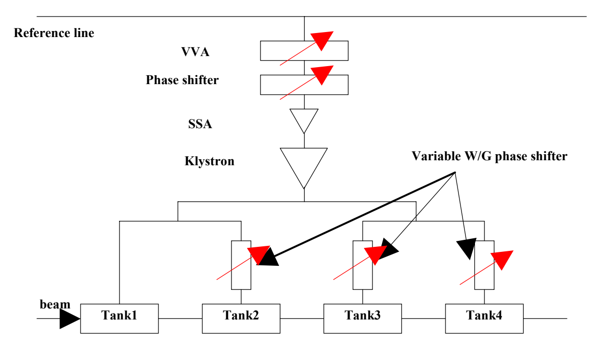

Figure 3: The schematic layout of RF delivery system.

RESONANCE CONTROL SCHEME

As stated earlier, the single RF source for multi-cavity scheme adopted for PEFP DTL make it impossible to use the LLRF system for resonance control of each tank because the changes made in the LLRF affect all of four tanks simultaneously. Therefore we need some other methods to control the resonance of each tank independently. For this purpose, we are going to use the thermal expansion of drift tube as an active frequency tuner. All of the drift tubes have a quadrupole

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electromagnet, so the thermal expansion of the drift tube can be controlled by adjusting the flow rate of coolant.

In addition to controlling the thermal expansion of drift tube, we have applied the heating cable and thermal insulation around the DTL tank for independent temperature control of DTL tank. The response time of temperature control is expected to be very long compared with the time scale of phase change of tank caused by beam loading, but such kind of fast phase change which is common for all tanks can be covered by LLRF system.

The Electromagnetic analysis coupled with the thermal analysis using SUPERFISH and ANSYS code was performed to investigate the effectiveness of this scheme and the results were summarized in table 1 and figure 4, 5. The condition 1 referred to the case in which the temperature of drift tube and DTL tank changes simultaneously and the condition 2 referred to the case where only the temperature of drift tube changes.

Table 1: Frequency Shift Due to Temperature Change

Cell		Condition 1 [kHz/℃]	Condition 2 [kHz/℃]
Tank 1	Low energy end	-5.47	-4.49
	High energy end	-5.29	-3.95
Tank 2	Low energy end	-5.29	-3.95
	High energy end	-5.20	-3.69
Tank 3	Low energy end	-5.20	-3.68
	High energy end	-5.15	-3.52
Tank 4	Low energy end	-5.14	-3.51
	High energy end	-5.11	-3.40

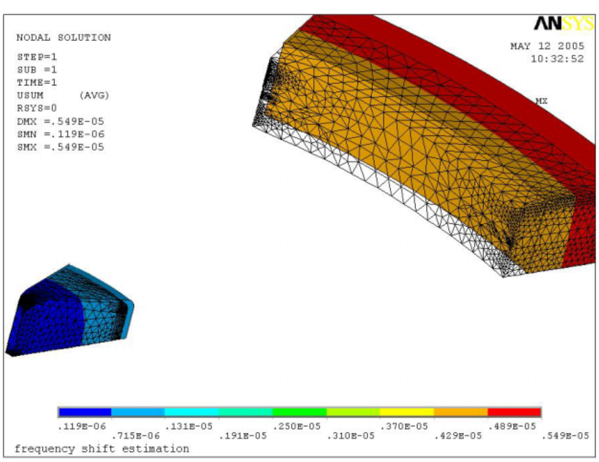

Figure 4: Thermal expansion analysis using ANSYS.

Because of the radiation shielding problem, the beam duty factor should be very low during the preliminary test of 20 MeV accelerator at KAERI site. Therefore the heating of the tank due to RF power loss is also very low, which makes the external heater control more suitable than the cooling control of the tank. We applied the heating cable of 2 kW for each tank and thermal insulation around the tank.

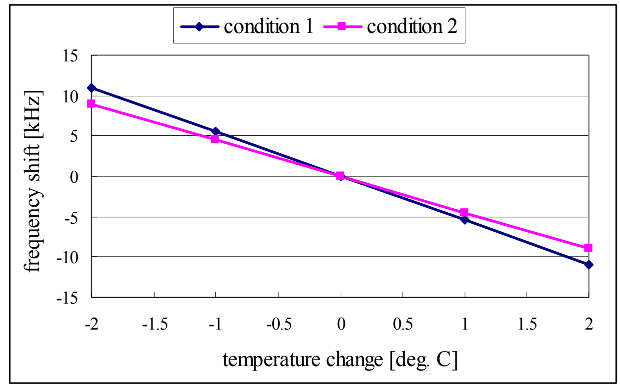

Figure 5: Frequency shift results for tank 1.

Heating power is controlled by PID method with SCR heater power supply. The installed heating cable around tank 1 is shown in figure 6. To see the resonant frequency response of tank, we made a step change of set point of PID temperature controller for heating cable and measured the resonant frequency as a function of time. The time trace of the measurement for 5℃ set point change can be found in figure 7. The resonant frequency fluctuation was less than ±500 Hz, which amounts to about ±0.1 ℃.

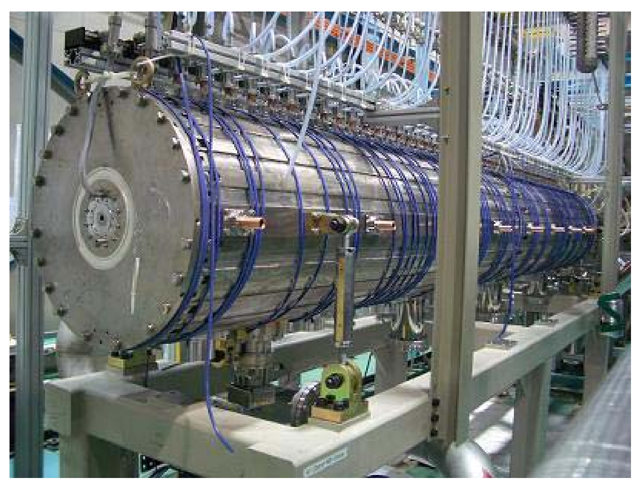

Figure 6: DTL tank 1 with heating cable.

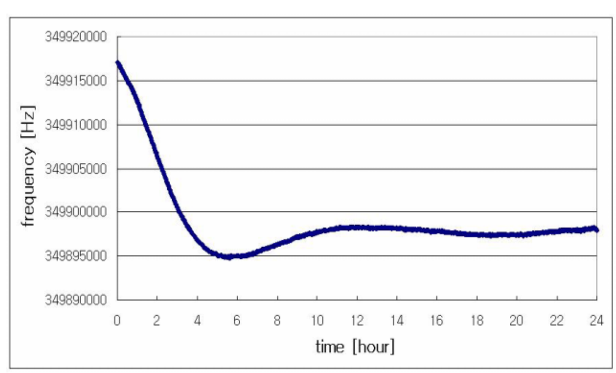

Figure 7: Frequency response to 5 ℃ step change.

OPERATIONAL SCHEME

RF Set Point Determination

All of four tanks are driven by single RF source, it is natural to install all four tanks and then start to test. In this case, however, it is difficult to tune each tank separately, because of following reasons. To tune the tanks separately, the measurement devices such as FCT or BPPM should be installed between tanks, because there are no empty drift tubes in DTL. Therefore the measurement devices should be installed between de-tuned tank due to limited space. This may affect the measurement accuracy because the beam drift long (about 4.5m) DTL tank without longitudinal focusing. Another problem is that the phase shift range of the mechanical phase shifter is ±22.5 degree. The usual phase scan ranges are ±10~±15 degree, therefore it is not possible to de-tune the successive tank entirely without removing RF power by methods such as installation a shorting plane or entirely detune the RF coupler and so on, which need disassembly of the waveguide system. Therefore it is planned to consider all four tanks as a single tank and tune them simultaneously.

There are several methods to determine the RF set point of the DTL. They can be summarized as bellows.

- 1: Phase scan with single phase measurement
- 2: Phase scan with phase difference measurement
- 3: Acceptance scan with energy degrader Faraday cup
- 4: Phase scan with signature matching
- 5: Beam loading scan with RF pick up

Scheme 5 is used as a initial coarse tuning, and then scheme 2 ~ scheme 5 are used for fine tuning. In this case there is no problem associated with installation space for measurement device.

Quadrupole Magnet Setting

Using the PARMILA code simulation and measured field gradient and effective length data, the quadrupole magnet set point which gives no beam loss was searched. It is found that no beam loss can be achieved by applying same setting to all of the QM except first two QM. Figure 8 shows the beam loss as a function of the field gradient of first two QM. The case in which no RF power was delivered except tank 1 was also studied and it was not possible to find no beam loss setting. For that case, however, it is still possible to find the setting which gives beam loss less than 0.2% by applying same setting to all of the QM, as can be seen in figure 9.

CONCLUSION AND FUTURE WORK

For preliminary test of PEFP 20MeV DTL, several schemes for resonance control, RF set point determination and quadrupole setting are setup. For PEFP DTL, it is convenient and more realistic to operate four tanks as if they were one tank. The construction of 20 MeV DTL for PEFP is almost finished and the preliminary beam test will be started in this summer according to the test scheme described in this paper.

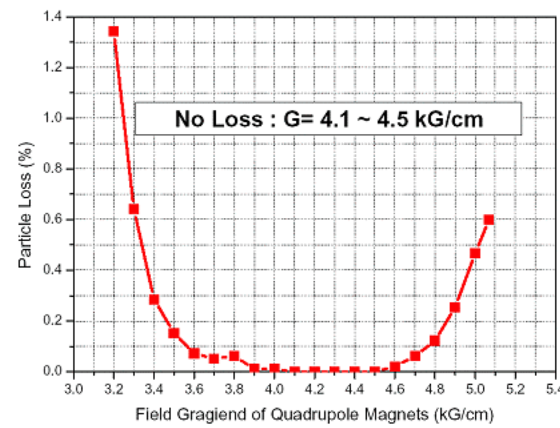

Figure 8: Beam loss dependency on the setting of first two quadrupole magnets.

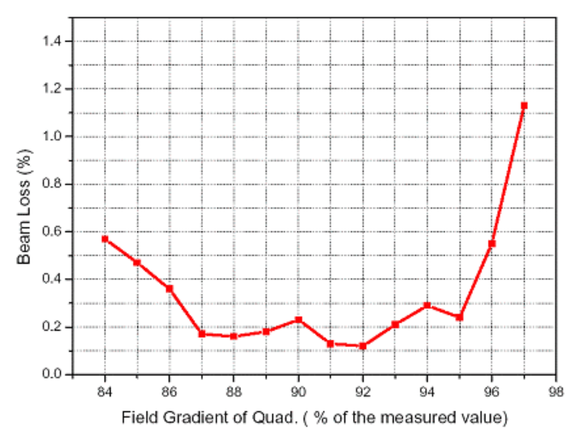

Figure 9: Beam loss dependency on the setting of all of the quadrupole magnets under RF power only in tank 1.

REFERENCES

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