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Accelerating Cavity Stabilization of the PEFP 20MeV Proton Linac

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1. Introduction

A 20 MeV proton linear accelerator (linac) has been developed at Proton Engineering Frontier Project (PEFP) as shown in Figure 1 [1]. The 20 MeV linac consists of 50 keV proton injector, 3 MeV radio frequency quadrupole (RFQ), and 20 MeV drift tube linac (DTL). Among those components, 3 MeV RFQ and 20 MeV DTL cavities are very sensitive to the operating conditions such as cavity wall temperature, cooling water temperature and also ambient temperature. Moreover, PEFP 20 MeV DTL has a unique characteristic that a single klystron drives four independent DTL tanks simultaneously. Therefore the stabilization of the operation parameters of the DTL is more important. In this paper, the stabilization methods of the operation parameters are described and the measurement results of the stabilized RF parameters are presented.

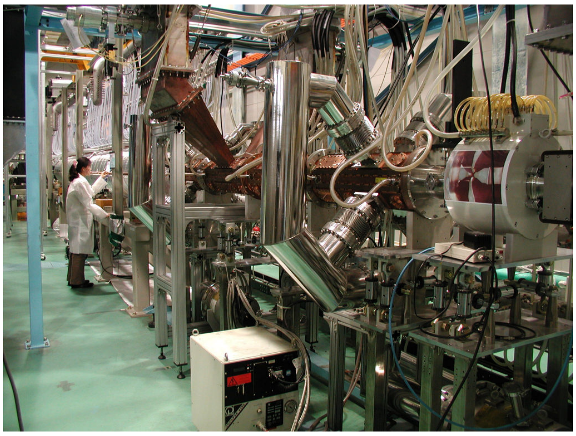

Figure 1. PEFP 20 MeV proton linear accelerator

2. Stabilization of the accelerating cavity

2.1 RFQ

The wall temperature should be maintained to 47.0°C to keep the resonance conditions. The electric heaters were used to adjust and stabilize the RFQ cavity. To minimize the ambient conditions, heat shields were installed around the cavity. An PID controller was used to control the wall temperature by adjusting the output power of the SCR power unit. It is not necessary to flow the coolant into the RFQ wall, because the operation duty is quite low (~ 0.01 %) during initial test. Therefore the wall temperature control by electric heater is the only control variable for cavity resonance conditions. The measured resonance frequency fluctuation with wall temperature control is shown in Figure 2. The resonant frequency could be stabilized with ± 1 kHz.

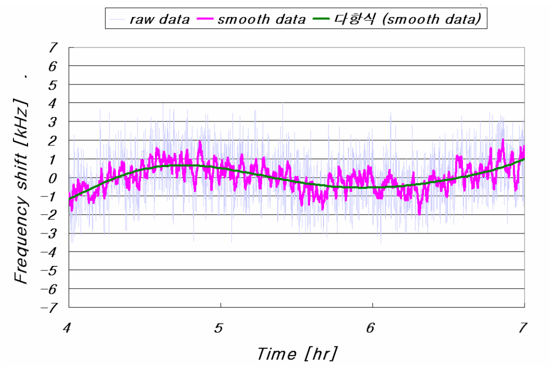

Figure 2. Resonance frequency variation of the RFQ

2.2 DTL

The PEFP 20 MeV DTL has a unique feature that one klystron drives four independent cavities. The RF control schematic is shown in Figure 3. Before the operation, the resonance frequencies of each tank are adjusted by using the heater installed on the wall of each tank independently. The resonant frequency fluctuations during the operation are controlled by the temperature of the cooling water which is supplied into the four tanks simultaneously. In this scheme, we can consider the four independent tanks into single cavity.

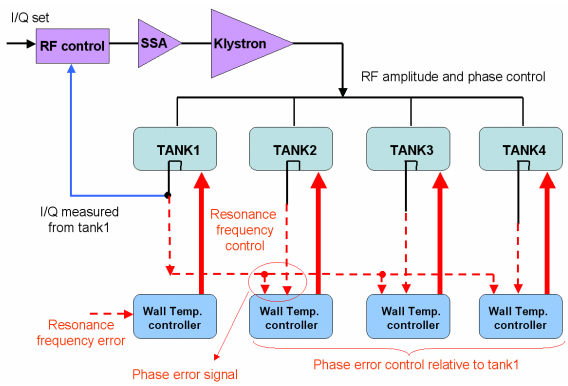

Figure 3. RF control scheme of PEFP 20-MeV DTL

The measured resonance frequency variation depending on the wall temperature is shown in Figure 4.

The wall temperature could be maintained within ± 1 kHz without coolant temperature fluctuation.

In contrast to the RFQ, cooling water is supplied to the drift tube of the DTL to cool the focusing electromagnet inside the drift tube. Therefore a 3-way control valve was installed to control the cooling water temperature. The control variables such as proportional, integral, and differential gains were sensitive to the ambient conditions. Therefore, we adjusted the control variables at every time before the test. One example of the various coolant temperatures and valve opening during the tuning stage of the control variables and accelerator operation stage are shown in Figure 5. The coolant temperature could be stabilized within ~± 0.1 °C during accelerator operation.

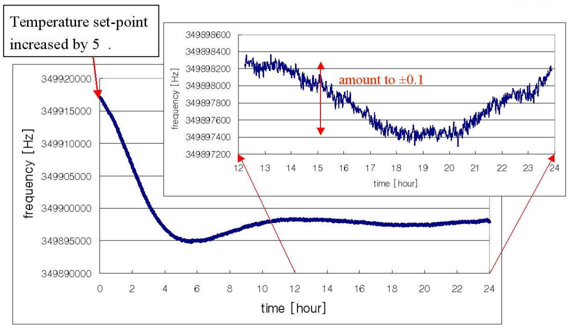

Figure 4. Dependence of the resonance frequency on the wall temperature of the DTL

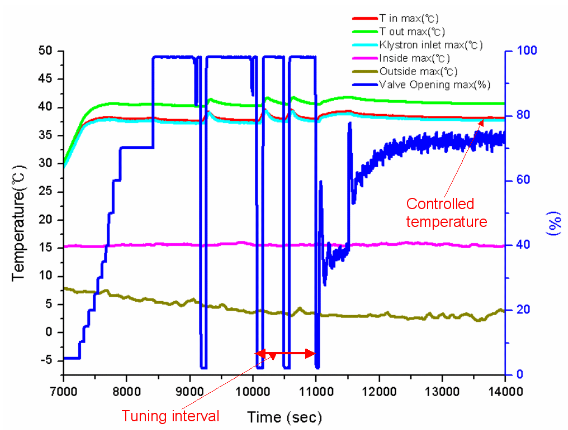

Figure 5. Various cooling water temperature variations during tuning and operation stages

3. RF Phase Measurement Between DTL Tanks

One of the key parameters that indicate the degree of the stabilization of the operation parameters is the relative RF phase variation between DTL tanks. The RF phases of each tank were measured with the reference phase of tank 2. One of the measured results during accelerator operation is shown in Figure 6. The peak RF power was 150 kW per each tank. The wall temperature variations of tank 1, tank 2 were maintained within ± 0.05 °C, but those of tank 3, tank 4 were within ± 0.2 °C. The coolant temperature was maintained within ± 0.15 °C with respect to the setting value. The standard deviations of the relative RF phase during accelerator operation were 0.47 °, 0.03 °, 0.85°, and 0.69 °. The measured values of the maximum phase variation of the tank 3 and tank 4 were ~ 2.6°, which reflect the wall temperature variations of 0.4°C, because the sensitivity of frequency on the wall temperature is ~ 1 kHz / °C, and RF phase on the frequency is ~ 6° / kHz.

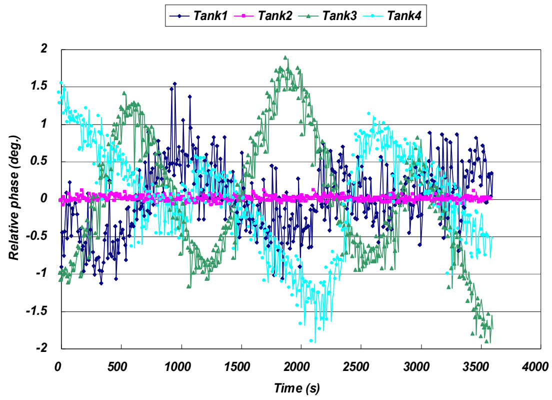

Figure 6. Relative RF phase variations of each tank during accelerator operation

4. Discussion and Conclusion

During the initial operation of the accelerator, basic stabilization methods were confirmed and the stabilization range of the operation parameters were measured. The re-adjustment of the control variables depending on the change of the ambient conditions is the remaining works to solve.

5. Acknowledgements

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Reference

[1] Byung-Ho Choi, "Status of the Proton Engineering Frontier Project", in the proceedings of PAC05, Knoxville, USA, 2005.