Proceedings of the Korean Nuclear Society Autumn Meeting
Yongpyong, Korea, 2003

The test of resonance control function for PEFP RFQ*

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Abstract

The RFQ (Radio frequency quadrupole) linear accelerator for PEFP (Proton Engineering Frontier Project) has been built, which is a low energy accelerator for 3MeV proton beam. To accelerate proton beam in the RFQ linear accelerator, the low-power RF System should have feedback control functions of cavity field (amplitude, phase), 350MHz cavity resonance frequency and high power protection. For the test of resonance control and phase control, one section of the RFQ with 4 movable tuners driven by step motors and the present LLRF (low-level RF) system with analog feedback control system have been used. In this paper, the test details and results are described.

1. Introduction

The RFQ linear accelerator for PEFP (Proton Engineering Frontier Project) has been built[1)], which is a low energy accelerator for 3MeV proton beam. To accelerate proton beam in the RFQ linear accelerator, it is necessary that the RFQ linear accelerator should maintain continuously 350 MHz resonance frequency.[2)] In addition to resonance control, the low-level RF System provides cavity field control function, and incorporates the personnel and machine protection functions.[3)] Resonance control is required in order to control the shift of the cavity’s resonant frequency due to RF heating, beam loading, cryogen pressure change, and variation in klystron high voltage.[4)] The shift of the cavity’s resonant frequency causes the variation of the cavity field (amplitude, phase). Thus, resonance control is a essential function for beam acceleration together with field control function.

For the test of resonance control and phase control, one section of the RFQ with 4 movable tuners driven by step motors and the present low-level RF system[2)] with analog feedback control system have been used.

2. Low-level RF System for RFQ

2-1. LLRF System

The RF system of the RFQ linear accelerator is composed of low-level RF system and high power RF system, as shown in Figure 1.
For beam acceleration, the functions required in LLRF system are listed below.[4)]

1) To provide the correct (frequency, amplitude, phase) RF carrier to RFQ
2) Cavity field (amplitude, phase) control function
3) Cavity's resonant frequency control function
4) The personnel and machine protection function

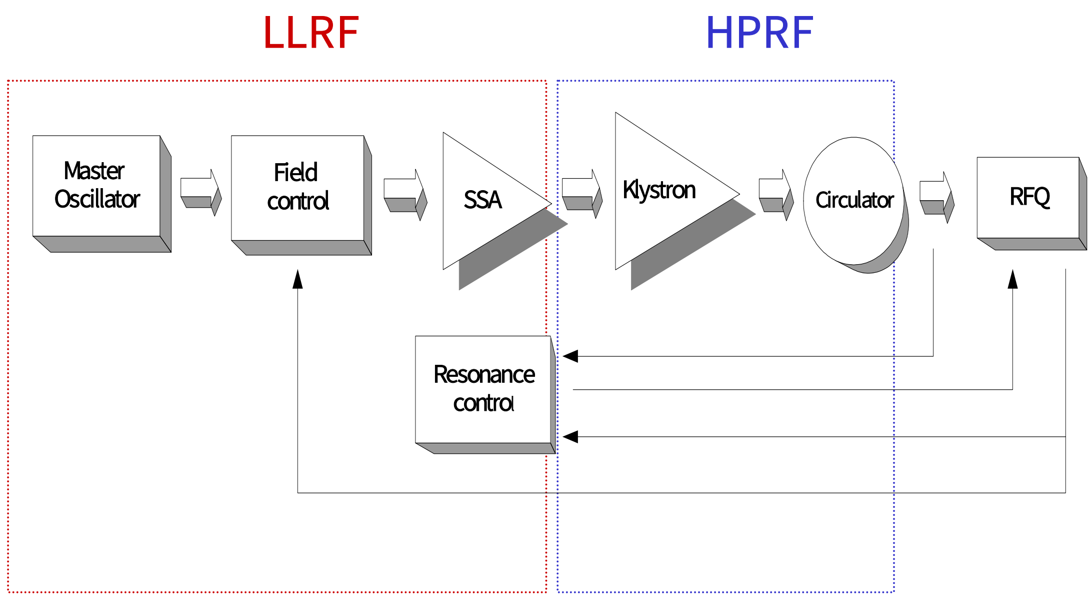

Fig. 1. The block diagram of the RF System for RFQ linear accelerator

2-2. The design of the LLRF System

The LLRF System Requirements for RFQ linear accelerator are listed below.

- Frequency : 350 MHz
- RF power level : 150 Watt
- field control : amplitude ±1%, phase ±1°
- Resonance control : water temperature control
  movable tuner control
- High power Protection
- Operation mode : CW, pulse

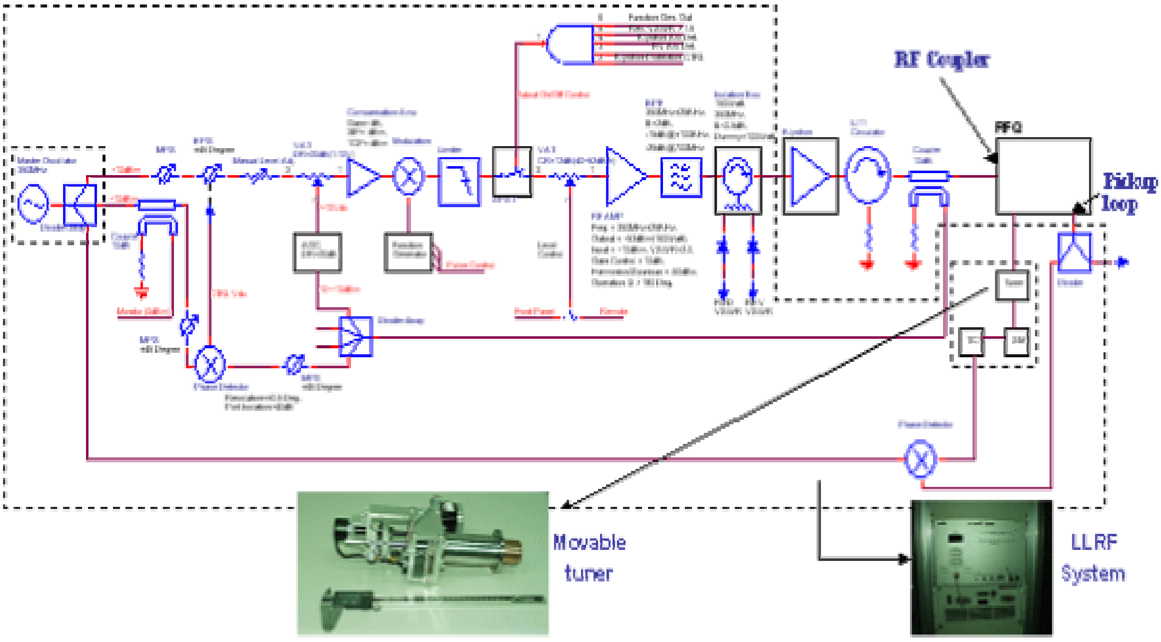

Fig. 2. LLRF System Block Diagram for RFQ

Table 1. LLRF System description

Description	Specifications
Center frequency	350 MHz
Stability	±350 MHz / 6 Month
Harmonics / Spurious	< -60 dBc
Bandwidth	±25 kHz
Final output power	52 dBm (160 W)
Automatic Level Control (ALC)	User settable
Level Control Range	> 20 dB
Phase Control Range	> ±45°
VSWR	2.0 Max
Modulation	OOK (on-off keying)
Isolation	> 20 dB (Dummy:100 W)
BPF	350MHz±25KHz, IL 2dB Max
FWD/BWD Monitor, Alarm protection Control and Monitoring, System Monitoring	Controller
Mechanical Dimension	19" Standard Rack

Figure 2 shows the LLRF System Block Diagram. The description of LLRF System is listed below. The design is based on the CW operation, but it can be operated in pulsed mode for the initial RFQ conditioning. RF switch (On-Off Keying) is used for pulse modulation. Pulse on time is 10mS, 100mS, 1S, 10S, CW and pulse off time is 100mS, 1S, 10S, CW off.

The RF source of 350 MHz is generated from the Master Oscillator with OCXO (Oven controlled crystal oscillator), PLL (Phase locked loop). The power level of Master Oscillator is 10 dBm and is monitored.

This System has interlock functions for high power RF System protection.

Field stability of ±1% in amplitude and ±1° in phase are required for the RF System in the RFQ linear accelerator. But, the present LLRF System with analog feedback control system has field control function of 1dB/step in amplitude and 1.4°/step in phase. Figure 3 shows the feedback control loop of the LLRF System. The potential unwanted phase drift of RF reference transmission line and feedback coaxial line will be considered for RFQ feedback control loop.

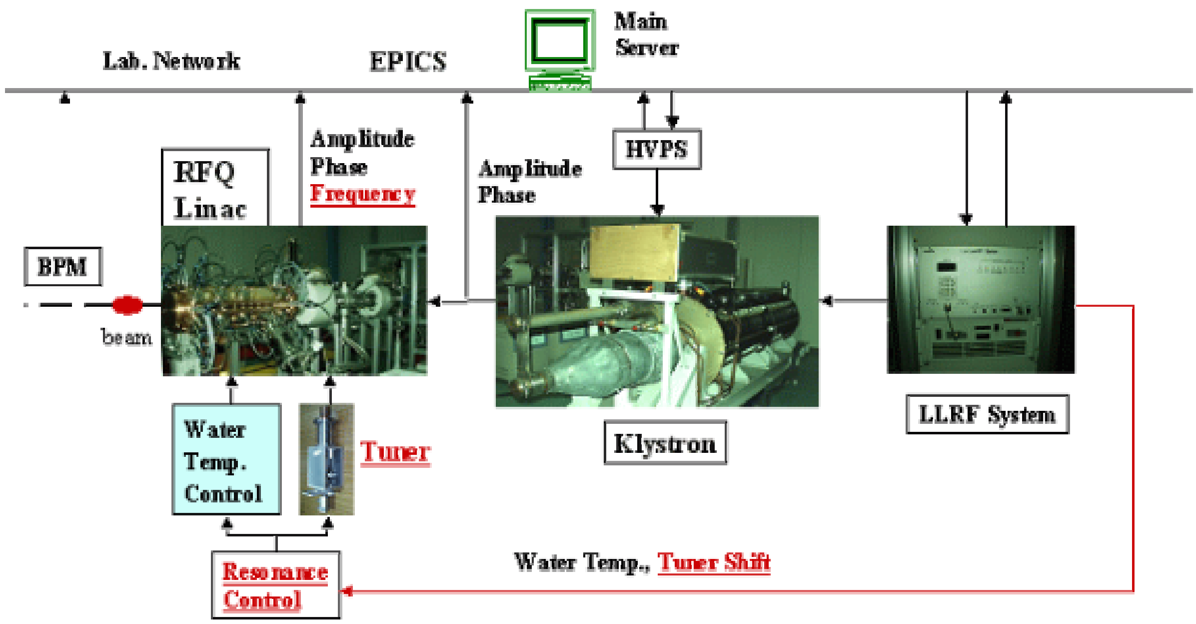

Fig. 3. The feedback control loop

3. The test of resonance and phase control function

In order to control the shift of the resonance frequency due to RF heating, beam loading, cryogen pressure change, variation in klystron high voltage, RFQ resonance control function is required.

Figure 4 shows block diagram for test. In this test, RFQ resonance frequency is controlled due to the variation of phase difference between the RF input coupler and the RF pickup loop. The variation of phase difference causes the output voltage of phase comparator to vary from reference voltage (0V), and the tuner controller shifts 4 movable tuners due to the output voltage variation of phase comparator. Movable tuners is shifted until equal to reference voltage, so cavity's resonant frequency (350MHz) is continuously maintained.

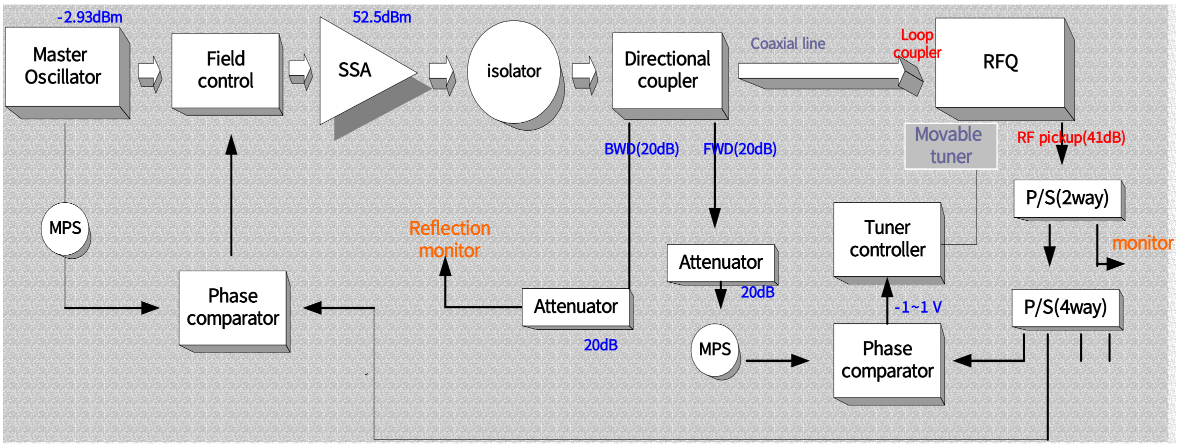

Fig. 4. The configuration for test

For the test of resonance frequency control function, one section of the RFQ with 4 movable tuners driven by step motors and the low-level RF system with analog feedback system have been used. Figure 5 shows the picture of RFQ resonance control test.

The parameters for the test of RFQ resonance control function are listed below.

- RFQ resonance frequency : 349.998MHz
- The coupling coefficient of input coupler : 0.929
- RFQ input power level : 51.71 dBm (148.252 Watt)
- RFQ pickup loop : - 41.243 dB
- Tuner controller : auto mode (-1~1 input voltage)
- 4 movable tuners driven by step motors
- Direction coupler (FWD, BWD) : 20 dB

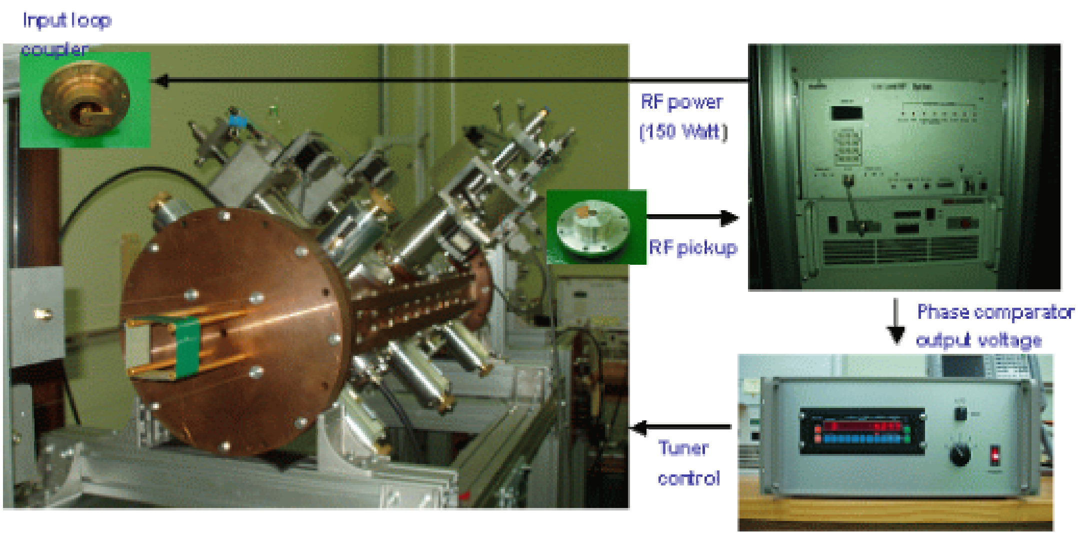

Fig. 5. The test of resonance control

Figure 6 and Figure 7 show RF input power and reflection power measured in resonance control test respectively. 20dB Attenuators and 20dB directional coupler were used in this test, so RF input power and RF reflection power level are respectively 51.71 dBm (148.252 Watt), 36.561 dBm (4.53 Watt).

Figure 8 shows the reflection power due to time variation. As shown in Figure 8, the reflection power is increased transiently by the operation sensitivity of tuner controller, movable tuner and phase comparator, but the reflection power is maintained at 36.5 dBm with time. Thus, it shows that RFQ resonance frequency continuously is maintained.

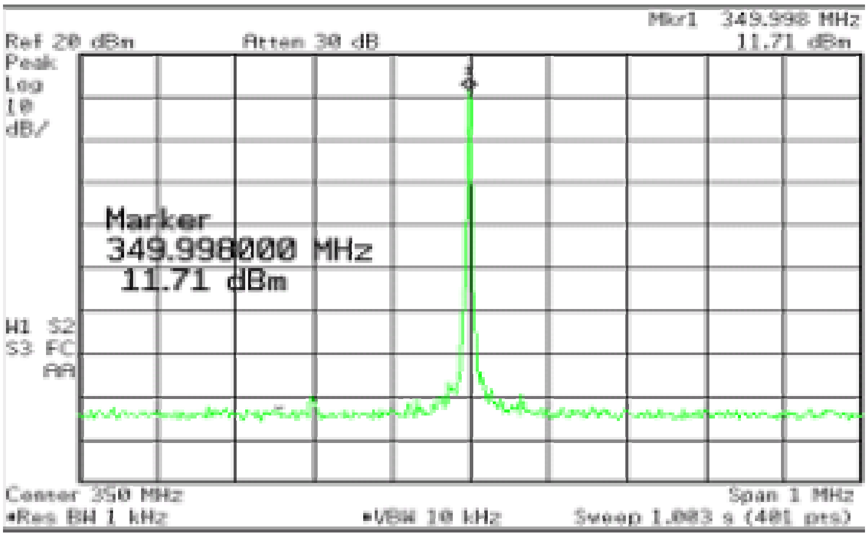

Fig. 6. RF input power

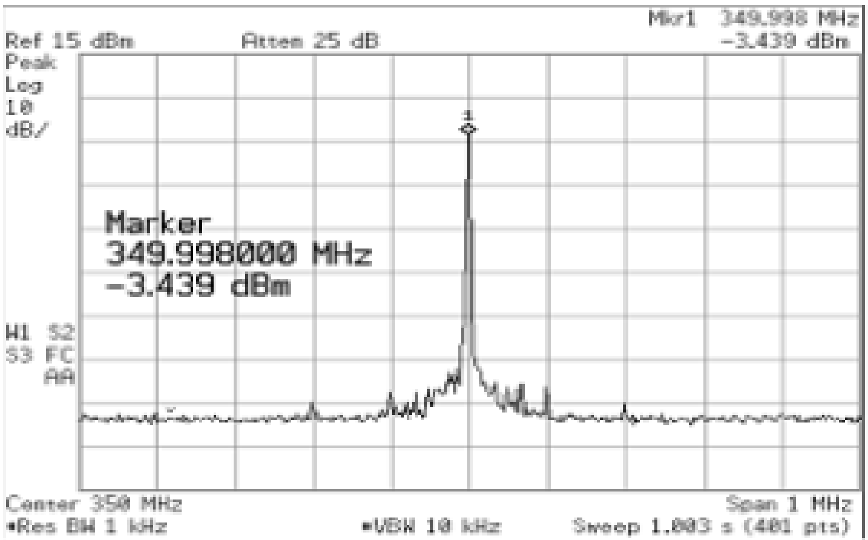

Fig. 7. RF reflection power

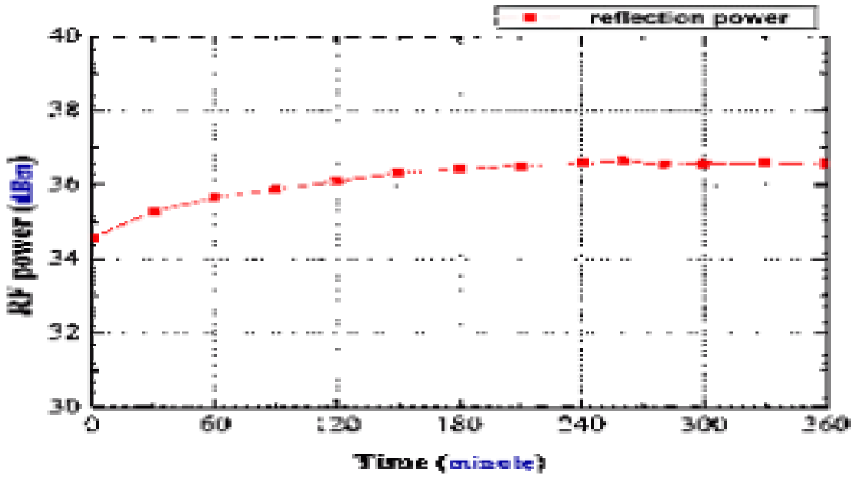

Fig. 8. RF reflection power measured due to time variation

4. Summary

For the test of resonance frequency control function for PEFP RFQ, one section of the RFQ with 4 movable tuners driven by step motors and the low-level RF system with analog feedback system have been used. In this test, RF input power is 51.71 dBm (148.252 Watt), and RF reflection power is 36.561 dBm (4.53 Watt). The measured results show that that RFQ resonance frequency continuously is maintained.

Points to be considered for the configuration and test of LLRF feedback control system are showed below.[4)]

- in order to control the shift of the resonance frequency, RFQ reflection power and the variation of phase difference will have to be controlled
- To minimize the error contribution, reference signal will be distributed in insulated, temperature-controlled coaxial lines
- will be temperature-controlled to eliminate potential unwanted phase drift.

Acknowledgement

* This work was supported by the Korea Ministry of Science and Technology.

Reference

[1] J.M. Han et al., "3.0MeV KTF RFQ Linac", Proceeding of APAC2001, Beihing, (2001).
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