THE CONSTRUCTION OF THE RF SYSTEM OF BEPC II

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Abstract

In this article, we'll introduce the RF system of BEPCII to readers. It consists of 4 subsystems: superconducting cavity, high power klystron, cryogenic system and LLRF. The construction of the RF system had been finished in late 2006. During the last year of running till now, it has performed very well.

INTRODUCTION

The upgrade of BEPC (BEPCII), began in early 2003. The RF system of BEPCII has been finished completely. The 500MHz Superconducting cavities have been used, which is characteristic. The whole RF system is made up of two separate subsystem, e+ and e-. Each subsystem consists of one superconducting cavity, one 250KW klystron and LLRF, etc. The work had been finished in Nov, 2006. The Figure 1 is the total system, and the Table 1 is the main parameters.

Table 1: the Main Parameters of RF System

The Parameters of RF System(the colliding mode)(e+ and e-)		
Parameters	**Symbol(Unit)**	**Data**
Frequency	f_{rf} (MHz)	499.8
Cavity Voltage	V_c (MV)	1.5
Energy Loss / Turn	U_b (keV)	135
Current	I_b (mA)	910
Beam Power	P_b (kW)	123
The Synchronous Angle	Φ_s (Deg)	174
The Number of Cavities	N_C	1
The Number of Klystrons	N_K	1
The Power of Klystron	P_{out} (kW/Klystron)	250
The Parameters of RF System(the synchrotron mode)		
Cavity Voltage	V_c (MV)	2.0
Energy Loss / Turn	U_b (keV)	336
Current	I_b (mA)	250
Beam Power	P_b (kW)	84
The Synchronous Angle	Φ_s (Deg)	167
The Number of Cavities	N_C	2
The Number of Klystrons	N_K	2
The Power of Klystron	P_{out} (kW/Klystron)	500
The Stability of System		
The Stability of the Phase	$\Delta\Phi$ (Deg)	±1.0
The Stability of the Amplitude	$\Delta V_d/V_a$ (%)	±1.0

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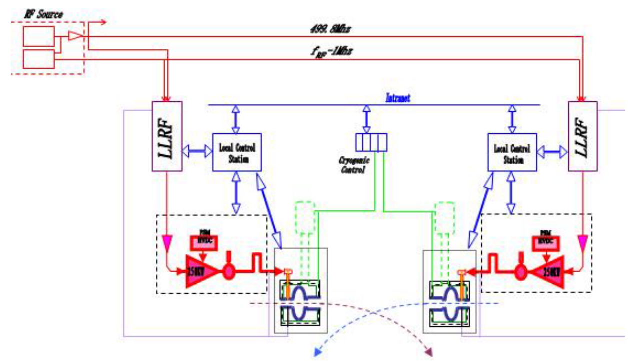

Figure 1: the RF System of BEPC II.

THE RF SYSTEM

The RF system is made up of 4 subsystems: superconducting cavity, high power klystron, LLRF and cryogenic system. In this section, we'll introduce the first 3 subsystems.

Cavity

There're two kinds of 500MHz superconducting cavities (CESR-C and KEK-B), which are deeply HOMs-damped, and both perform well. We have chosen the later. Figure 2 is the KEK-B superconducting cavity.

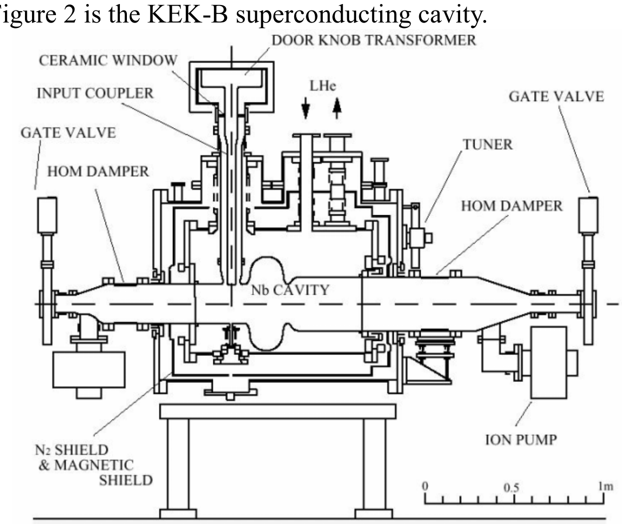

Figure 2: KEK-B Superconducting Cavity.

The 508 MHz KEK-B cavity can't be directly used in BEPC II. With help from the KEK experts, we finished the work of modifying frequency. The new design is fit for the frequency of BEPC II, beam current and assembly. We enlarged the length of the meridian, reduced the length of coupler, and placed a photon-absorber at the vacuum tube. The cavity of BEPC II would achieve the following target, as Table 2 shows.

Table 2: the Performance of the Cavity

RF Properties		**High Power Window**	
V_{acc}	> 2.2MV, 2.3MV	Travelling Wave	300 kW
Q_o	> 5.6×10^8, 8.9×10^8 (at V_{acc} = 2.0MV)	Power at Full Reflection	150kW (Cavity off Resonance)
Q_{ext} of Input Coupler	1.8×10^5, 2.1×10^5		
Tuner	499.8 ± 0.1 (with resolution 5 Hz)		
Static Losses	< 30 W		

When running, the cryogenic system supplies helium liquid and nitrogen liquid needed. The target: pressure(±3mBar), the liquid level (±1%).

When the temperature of the superconducting cavity is rising or declining, the speed is about 3-5K/h.

Power Supply and Transmission

We invited public bidding for the klystron over the world in middle 2003, and chose the 500MHz/250KW klystron and its electrical source of THALES, France. The two klystrons had been assembled in late 2004 and early 2006, and reached the goal designed.

Table 3: the Performance of the BEPC II 500 MHz /250 kW RF Power Source

1. Technical Goal	
Frequency	499.8 MHz
3 dB Bandwidth	>+/- 1MHz
Amplitude Error (Frequency Error < ±300 kHz)	≤0.3 dB
RF Power Output (After the Circulator)	250kW CW
Max SWR	1.2
RF Output Waveguide	WR1800
The Input Power of the Solid Amplifier (Output Power 20 W)	≤2 mW
RF Input Impedance	50
The Input Power of Klystron (Output Power 180 kW)	≤20 W
Input VSWR	≤1.2
RF Input Linker	N (female)
Max Single Harmonic (250 kW Output)	-30 dB
The Shutting Time of HV Electrical Source	≤10 ms
The Power Released to the Klystron after the Shutting of the HV Electrical Source	≤10 J
2. Safety	
X-Ray Radiation	≤0.1 μSv/h
RF Radiation	≤0.1 mW/cm^2

We chose the WR1800 of MAGE, USA as the transferring waveguide. The high-power circulator is the product of AFT, Germany.

Low Level Control System

The LLRF is for the feedback-control and the quick protection of the system. It consists of signal source, interlock circuit and several feedback loops. Table 4 shows the performance of the LLRF. Figure 3 displays the theory of the LLRF system.

Table 4: the Main Technical Index of LLRF

Number	**Item**	**Technical Index**
1	Interlock	Response time<10ms
2	The Phase Loop	Range: ±45 degree, Resuming time < 2 ms, Open-loop gain > 40db, the bandwidth of the loop amplifier adjusted between 1 and 10KHz, to ±20db Power error, Closed loop precision: ±1degree
3	The Amplitude Loop	To 50% step error, Resuming Time < 2 ms, Open-loop gain > 40db, the bandwidth of the loop amplifier adjusted between 1 and 10KHz, to ±20db Power error , Closed loop precision: ±1%
4	Auto Tuning	Range: ±45 degree, Tuning range: 400khz, Precision: 10KHz, Bandwidth > 50Hz
5	The Lognitudinal Feedback	Above 20dB damping of the longitudinal oscillation

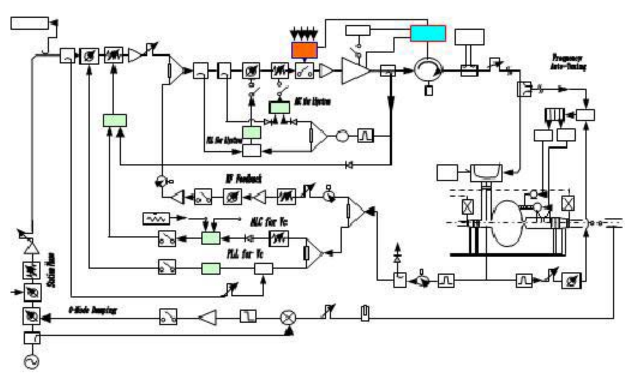

Figure 3: the Theory of the LLRF System.

In order to keep enough safety under 930mA beam current, we have taken two measures: 1, pre-tuning a small angle; 2, RF feedback. When the beam current is 200mA, 40% RF feedback performs well and pre-tuning badly.

THE MAINTENANCE FACILITY OF SUPERCONDUCTING CAVITY

According to the advice of experts from KEK and Cornell, the maintenance facility for the superconducting cavity is very necessary. We have established a RF superconducting lab in IHEP. It includes a big Class 100 clean room, the high-pressure pure-water washing machine, surface post-treating facility of niobium cavity and the hole for vertical test. These are very useful for the maintenance.

There's a high power testing room for the superconducting cavity. The test bench for the high power input coupler is in progress.

THE INTEGRATION OF THE SYSTEM

The RF system consists of 4 subsystems: superconducting cavity, high power klystron, cryogenic system and LLRF, assistant facility as well. Most equipment is imported or made by companies. When the subsystems passed the test separately, the integration and test of the whole system is important. Because of the hard work of us, the test of the system succeeded at the first test. Then the RF system began the beam-test running in Dec, 2006.

CONCLUSION

During the past year, the RF system of BEPCII performed well. It achieved the technical index. So the design and construction of the system is successful. In future, we'll work hard to improve the stability, collect useful experience and make it criterion.

Cooperation and communication are necessary to develop RF technology. Thanks for the experts from KEK. They helped us much during the construction of RF system. And we also learned much knowledge and experience from them. Thanks for the colleagues from SSRF in Shanghai, too.