HLS RF SYSTEM IMPROVEMENT IN NSRL PHASE II PROJECT

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Abstract

Hefei Light Source (HLS) is mainly composed of an 800 MeV electron storage ring and a 200 MeV Linac functioning as its injector. The RF system has been improved successfully for HLS storage-ring in NSRL Phase II Project. In this paper, the improvement of the RF transmitter and power transmission system, the development of a new RF cavity and the perfection of RF controls are described in detail. The results and some analyses are presented.

INTRODUCTION

Hefei Light Source (HLS) is mainly composed of an 800 MeV electron storage ring and a 200 MeV Linac functioning as its injector. On the machine side, the goals of the NSRL Phase II Project upgrading plans are: (1) Regular operation of General Purpose Light Source (GPLS) mode with typically 300 mA accumulated current in every fill, with more-than-8-hours lifetime. (2) Alternatively, regular High Brightness Light Source (HBLS) mode operation with 150 mA current of 4 hours lifetime [1]. HLS Radio Frequency system consists of the RF power source with the power transmission line, the RF cavity and the RF controls. The improvements of RF system were fulfilled in NSRL Phase II Project as follows:

- A CW power of 30 kW RF transmitter was increased, who can be used with another one by a switch for maintaining the equipments convenient and advancing the machine operation effectiveness. A 30 kW circulator and several coaxial directional couplers were used in the RF transmission system for ensuring the transmitter security and monitoring the system operation status in time.
- A new RF copper cavity, which operating frequency of 204 MHz, power handling capability up to 20 kW was developed to establish a sufficient RF gap-voltage of cavity for accelerating beam current from 200 MeV to 800 MeV and maintaining acceptable quantum lifetime and suitable bunch length.
- The cavity amplitude loop, the tuning loop and the interlocks were installed in the RF system for keeping the cavity gap-voltage constant, adjusting the cavity tuned status and protecting the equipments safety. The all RF parameters and the low level controls can be collected and processed by the OPI Sun Workstation in centre control room.

The RF system has been improved successfully for HLS storage-ring. In this paper, the improvement of the transmitter and power transmission system, the development of a new RF cavity and the perfection of RF controls are described in detail. The results and some analyses are presented.

RF POWER AND TRANSMISSION

HLS RF station consists of the RF power source with the power transmission system and a RF cavity. A block diagram is shown in Fig. 1. In NSRL Phase II Project, a RF transmitter with CW power of 30 kW was increased, who can be used with another one respectively by a coaxial switch. It is convenient to maintain the transmitter and the operating effectiveness of storage ring has been advanced greatly. A circulator with 25 kW CW power capability (both forward and reflected) is required to redirect reflected power coming toward the RF tetrode and to guarantee stable tetrode operation. The circulator with Temperature Compensating Unit (TCU) produced by AFT was used in high power transmission system as shown in Fig. 2. A small VSWR between the transmitter and the port-1 of circulator has been kept in operation. Several coaxial directional couplers were installed on appropriate places of the 3 1/8〞coaxial transmission lines. The forward power, the reflective power, some low-level and interlock signals are available for monitoring the operation status in time and ensuring the RF system safety.

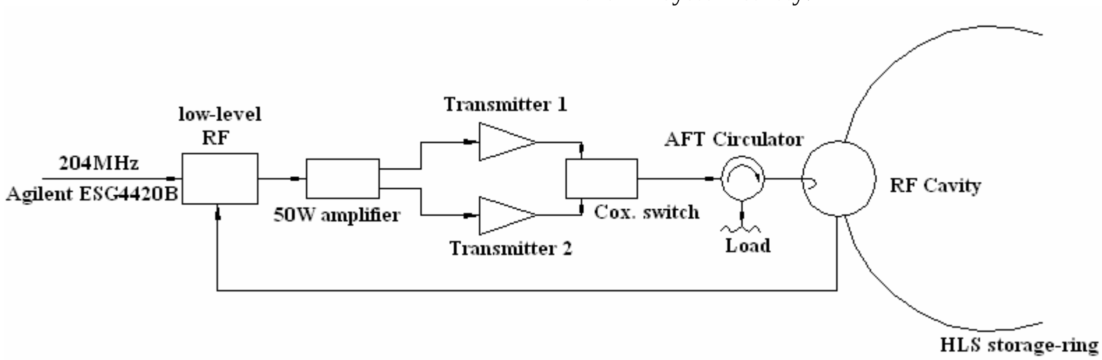

Figure 1: Block diagram of HLS RF system.

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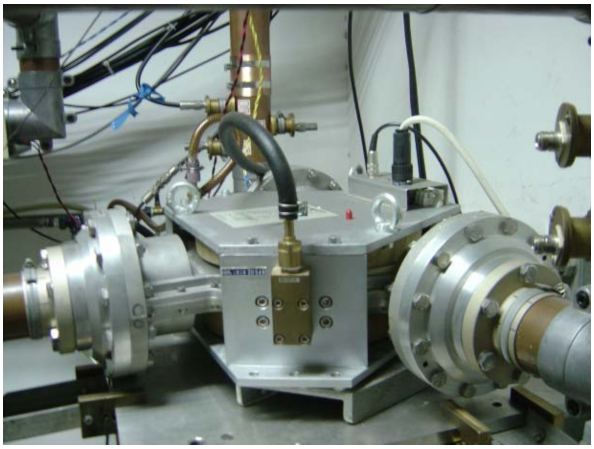

Figure 2: RF circulator on line.

The parameters of RF transmitter and power transmission system are summarized in Table 1.

Table 1: RF station specifications

Parameters	**RF station**
Output power of transmitter	30kW
Operation power of transmitter	15.4kW
Harmonics / fundamental mode	< -49dB
losses of transmission line	0.3dB
Forward and reverse power of circulator	25kW
VSWR of circulator (port-1)	<1.1

HLS CAVITY DEVELOPMENT

A new RF cavity has been developed [2]. To point at the problems appeared in the original cavity (made in Phase Ⅰ Project), the choice of the cavity material, the selection of the cavity shape and the improvement of cooling type were paid special attention in design and fabrication. The shape optimization, RF parameters calculation and power density distribution on the cavity wall were numerical simulated with SUPERFISH-Code. High Order Modes (HOMs) were investigated primarily with URMEL-T.

A re-entrant type cavity is adopted. It consists of five parts: a centre-body-section, two end caps and two noses with beam pipes. In the centre-body-section, there are ten openings: a coupler port, a vacuum pumping port, an observation port, a vacuum measurement port, two pick-up ports, two tuners ports and two ports for the HOMs restrainers. There are another 4 ports on the end cap for the antenna-type and loop-type HOMs dampers. The geometry construction of the cavity is shown in Fig. 3.

The most critical aspects of fabricating the shell were surface finish, dimensional control of the capacitance loading plates (noses), welding and ultra-high vacuum cleanliness. The main fabrication technology of HLS cavity is described [2].

An input coupler with coupling factor of 2 is adopted so that to transfer a higher CW power to cavity effectively and maintain a match between the final RF amplifier and cavity in operation with a larger beam-loading. The coupling structure of input coupler is a rectangle loop connected to the 50 Ω coaxial transmission line. The loop dimensions were optimized by 3D (x, y and z) MAFIA-Code [3] and its coupling area (150×32 $/mm^2$) was determined. In coupler fabrication, the ceramic window coated several dozen Å of Titanium Nitride (TiN) was brazed in coaxial transmission line of coupler so that to obtain an excellent vacuum in cavity and to reduce multipactor in high power operation. Also the cooling structure was considered for both of the coupling loop and the window.

The frequency tuner can compensate frequency error effectively so that to keep the cavity in tuned status. In view of the change of the beam current, the frequency tuning range of $\Lambda f =$ 79.3 kHz can be acquired. Besides beam loading effect, there are other factors to cause resonance frequency error, such as temperature, welding, vacuum and tune away the harmful HOMs and so on. Summing up the factors as mentioned above, two tuners with tuning range of 300 kHz respectively are adopted. One is fixed and the other is movable automatically according to frequency error. Both of the tuners are plunger type. A 3D (x, y and z) geometry model was constructed and the dimensions of tuner were optimized by MAFIA-code [3]. A 115 mm diameter by 7 cm travel plunger turner was determined. The tuning curve of cavity frequency versus turner travelling depth is acquired. The cavity was final assembled by installed two tuners, two pick-up couplers, an input coupler, a quartz observation window, a vacuum measurement gauge and a 400 liter/sec ion-pump to the cavity body. The plungers were tuned to appropriate placement for operation frequency and a coupling factor of 2 was obtained by rotating the coupling loop from the beam axis about 60^o. All RF parameters were measured with the Network Analyzer HP 8722D. In order to get an ultra-high vacuum, a 150□ vacuum bake was performed and a pressure of 3.4×10^{-8} Pa was achieved in 72 hours high temperature processing. In high power testing, the water with 42.5 ℃ was adopted for cooling cavity. The frequency-tuning-loop and the cavity-amplitude-loop were used to compensate frequency error and to keep the gap-voltage constant effectively. A cavity gap-voltage of 278 kV was obtained for operation a CW power of P_c =10.5 kW dissipated in the cavity, where the cavity shunt impedance, R_s, = 3.7MΩ. The main measurement parameters of the RF cavity are shown in Table2.

Table 2: The main parameters of the HLS cavity

Parameters	**HLS cavity**
Frequency （f ）	204 MeV
Max. RF gap voltage of cavity (V_c)	260 kV
Shunt impedance (R_s)	3.7 MΩ
Unloaded Q value (Q_o)	28300
Coupling factor (β)	2.02
Tuning range (Δf)	>300kHz
Temperature (T)	42.5 ℃
Vacuum	3.4×10^{-8} Pa

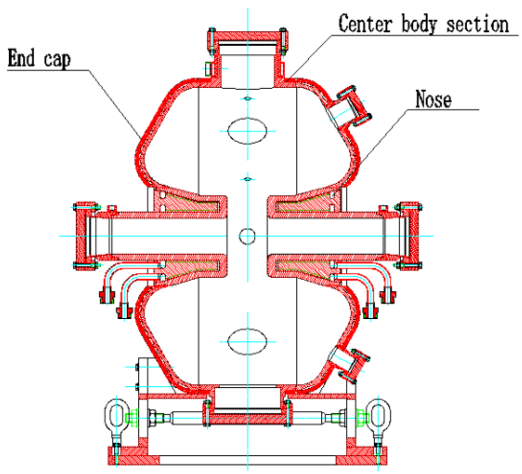

Figure 3: The sketch of HLS RF cavity.

RF CONTROLS

The low level controls of HLS RF system consists of two feedback loops, interlocks and protection system. The tuning loop can compensate frequency error effectively for either detuning by the beam or temperature effects. The loop measures phase across its cavity and moves the corresponding tuner to keep the cavity tuned status (the frequency tuning accuracy about ± 100 Hz). The cavity-amplitude-loop keeps the gap voltage constant by measuring the magnitude of the cavity field and comparing it to a reference voltage. The loop then adjusts variable attenuator in the RF reference to the RF feedback loop to keep the gap voltage constant (the cavity voltage constancy <0.3%).

The protection signals are received in the centre process unit (SCM) and the RF path status (on, off) can be controlled by a PIN switch as shown in Fig. 3. The interlocks of the circulator arcing (the total power dissipation < 5 J, delay time for arc detection <150 µs), the circulator cooling flow (<400 *L/h* , delay time <200 ms) and the cavity vacuum (>1×10^{-5} Pa, delay time <200 ms) were joined in system. The others, like the power limit, reflect protection etc. have been considered. The interlocks system has worked well since it was operated.

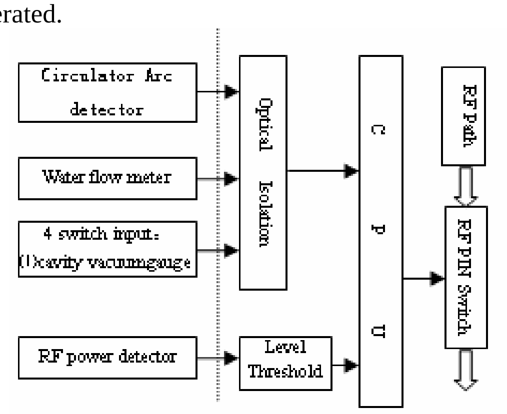

Figure 4: The Diagram of interlocks circuit.

The all RF parameters and the low level controls can be collected and processed by the OPI Sun Workstation in centre control room. The Hardware structure of HLS storage ring new RF control system is shown in Fig. 5.

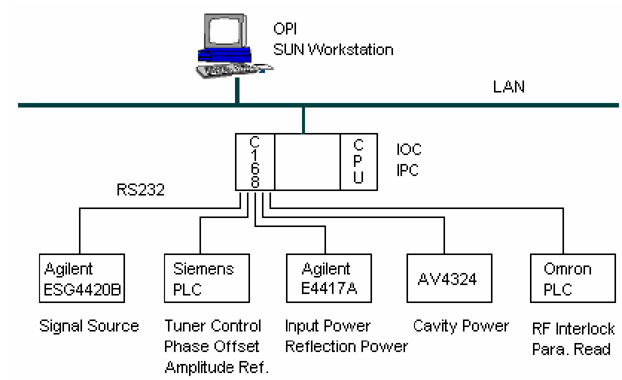

Figure 5: Hardware structure of HLS storage ring new RF control system.

SUMMARY

The RF system for HLS storage-ring has been improved successfully in NSRL Phase II Project. The HLS RF cavity was installed on the 800 MeV storage-ring in May, 2003 as shown in Fig.6 and has been operated in a fine status. The typically 300 mA accumulated current in every fill, with more-than-8-hours lifetime for General Purpose Light Source (GPLS) mode is realized. The basic operation condition of High Brightness Light Source (HBLS) mode is ensured due to a cavity-gap-voltage of 278 kV has been achieved.

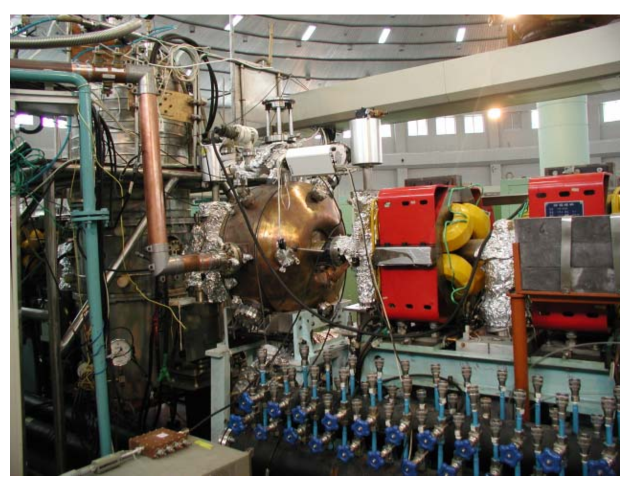

Figure 6: The HLS RF cavity installed on 800MeV electron storage ring.

REFERENCES

[1] Z. Liu and X. Zhang, NSRL Phase II Project (a Brief Introduction and Status), SRI'97, Himeji, Japan, Aug. 1997; also J. Synchrotron Rad., (1998).5
[2] K. Jin, et al., HLS RF Cavity Development in NSRL Phase II Project, to be published in "NIMA (2005)".
[3] MAFIA, the MAFIA Collaboration, December 1996.