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STATUS AND PROGRESS OF THE HIGH-POWER RF SYSTEM FOR HIGH ENERGY PHOTON SOURCE

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Abstract

High Energy Photon Source is a 6 GeV diffraction-limited synchrotron light source currently under construction in Beijing. Three types of high-power RF systems are used to drive the booster and the storage ring. For the booster ring, a total of 600 kW continuous-wave (CW) RF power is generated by six 500 MHz solid-state power amplifiers (SSA) and fed into six normal-conducting copper cavities. Concerning the storage ring, five CW 260 kW SSAs at 166 MHz and two CW 260 kW SSAs at 500 MHz are used to drive five fundamental and two third-harmonic superconducting cavities respectively. The RF power distributions are realized by 9-3/16" rigid coaxial line for the 166 MHz system and EIA standard WR1800 waveguide for the 500 MHz one. High-power circulators and loads are installed at the outputs of all SSAs to further protect the power transmitters from damages due to reflected power although each amplifier module is equipped with individual isolators. The overall system layout and the progress of main components are presented in this paper.

INTRODUCTION

High Energy Photon Source is a 6 GeV diffraction-limited synchrotron light source currently under construction in Beijing [1, 2]. A double-frequency RF system has been adopted with 166.6 MHz as the fundamental and 499.8 MHz as the third harmonic, while five 500 MHz PETRA-type copper cavities are used for the booster ring [3].

The main parameters of the HPRF systems are listed in Table 1. Solid-state power amplifiers (SSAs) have been adopted for all HPRF systems of HEPS by taking account of the advantages of high modularity, high redundancy, ease of maintenance and exempt from high voltage [4]. For the booster ring, a total of 600 kW continuous-wave (CW) RF power is generated by six 500 MHz SSAs. Concerning the storage ring, five CW 260 kW SSAs at 166 MHz and two CW 260 kW SSAs at 500 MHz are used to drive five fundamental and two third-harmonic superconducting cavities respectively. The power of the SSA is determined based on the required power by each cavity and the estimated power dissipation in the transmission line (TRL), as well as the consideration of a certain power margin.

LAYOUT

Three high-power RF (HPRF) systems distributed in two rings are being developed to drive the corresponding accelerating cavities. The RF power distributions are realized by 9-3/16" rigid coaxial line for the 166-MHz system and EIA standard WR1800 waveguide for the 500-MHz one. For each HPRF system, High-power circulators and loads are installed at the outputs of all SSAs to further protect the power transmitters from damages due to reflected power although each amplifier module is equipped with individual isolators. Water loads instead of ferrite loads are chosen.

Booster HPRF System

Figure 1 shows the layout of the Booster HPRF station located at the booster ring. It consists of six sets of systems shown in Fig. 2. The RF power from each SSA is transported to the cavity by EIA WR1800 waveguides. The waveguide system includes one high-power circulator, one high-power water load, nine flex waveguides, various straight sections and E and H-plane bends,three directional couplers arranged at the three ports of the circulator and one directional coupler placed close to the fundamental power coupler (FPC).

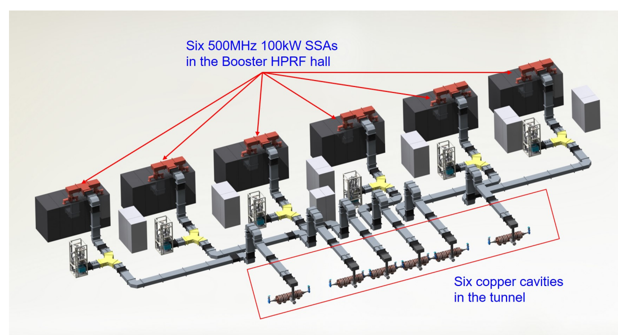

Figure 1: Booster HPRF station layout.

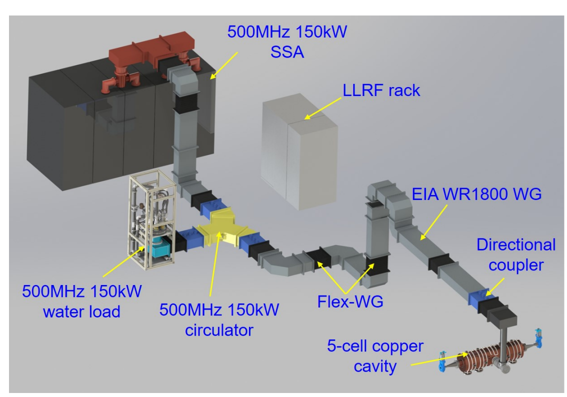

Figure 2: Single set booster HPRF system layout.

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Table 1: Main Parameters of the HPRF Systems

Parameter	Booster	Main SR	Harm. SR
Frequency [MHz]	499.8	166.6	499.8
RF source type	SSA	SSA	SSA
TRL type	WR1800 WG	9-3/16” coaxial line	WR1800 WG
Power per cavity [kW]	CW, 70	CW, 180	CW, 200
TRL power loss [kW]	CW, 10	CW, 20	CW, 20
Power per source [kW]	CW, 100	CW, 260	CW, 260
No. of cavities	6	5	2
No. of RF sources	6	5	2
Isolator power [kW]	CW, 150	CW, 300	CW, 300
Load type	Water load	Water load	Water load

Storage Ring HPRF System

The layout of the storage ring HPRF station located at the storage ring is shown in Fig. 3. All the transmission lines are placed on the racking platform with the LLRF rack under the platform to save space and shorten transmission lines. Five 166 MHz SCCs are adopted for phase I and three more are reserved for phase II . Maze structures are developed for radiation shielding.

Each platform is shared by two sets of 166 MHz HPRF systems as shown in Fig. 4. The RF power from each SSA is transported to the cavity by 9-3/16” inches rigid coaxial lines. The coaxial lines system includes one high-power circulator, one high-power water load, several flexible units, various straight sections and 90 ° elbows, one direct access unit, three directional couplers arranged at the three ports of the circulator and one directional coupler placed close to the FPC. Special-designed bending structures are adopted for easy installation and dismounting. In addition, the return loss of the entire line can be adjusted by a slot structure on each bend. By adopting the direct access unit [5] near the FPC, the TRL itself and the loaded quality factor of the cavity shall be measured directly without dismounting the coaxial line. Figure 5 shows the layout of the single set SR harmonic HPRF system, which is similar with the booster HPRF system.

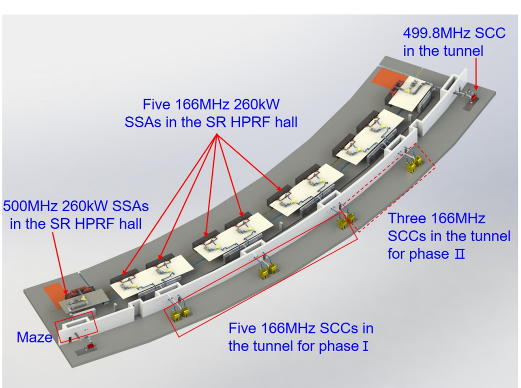

Figure 3: Storage ring HPRF station.

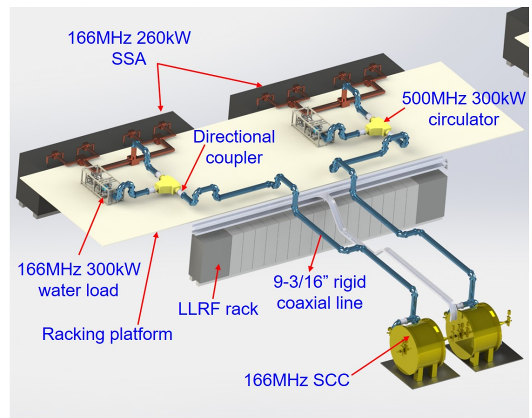

Figure 4: Two sets of SR main HPRF system.

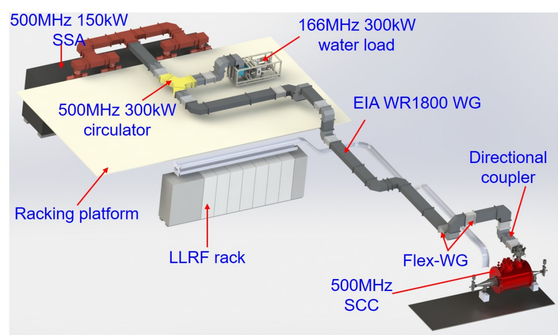

Figure 5: Single set SR harmonic HPRF system.

KEY COMPONENTS PROGRESS

Most of the components have been domestic-developed except for the high-power circulators. The status and progress of the key componnets will be described below.

Solid-state Power Amplifiers

For the 166.6 MHz 260 kW SSA, a total number of 112 amplifier modules of 3 kW each are combined in a multi-stage power combining topology [6]. Finally, eight signals from eight cabinets are sent to a high-power 8-way combiner to deliver an output power of 260 kW through the 9 inches rigid coaxial line. The first prototype 166.6 MHz SSA is

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under factory acceptance test now, as shown in Fig. 6(a). And for 500 MHz 150 kW SSA, a total number of 96 amplifier modules are combined initially by coaxial and later by waveguide combiners [7]. The final output is of EIA standard WR1800 rectangular waveguide. The first prototype is under cabinet adjusting now and will be high-power tested in July 2021.

(a) (b)

Figure 6: Solid-state amplifiers: (a) 166.6 MHz 260 kW SSA under factory acceptance test; (b) Single cabinet of 500 MHz 150 kW SSA under assembly.

Transmission Lines

One prototype 9-3/16" rigid coaxial line system including the straight line, 90 ° elbow, flexible unit, directional coupler and direct access unit has been developed and tested recently, as shown in Fig. 7. Both LLRF measurement of the return loss and insertion loss and the high-power RF test up to CW 260 kW have been done and demonstrated excellent mechanical and rf performance.

(a) (b)

Figure 7: Transmission lines: (a) 9-3/16" rigid coaxial line prototype under factory acceptance test; (b) WR 1800 WG prototype under high-power test.

One prototype WR1800 waveguide including the straight sections, E and H-plane bends, flex-WG and directional couplers. Satisfactory performance of these components has been verified by low power and high-power test. Especially, a directivity of 48 dB has been achieved for the directional coupler, largely exceeding the required directivity of 30dB.

High-power Isolators

All the high-power circulators have been ordered from Ferrite Microwave Technologies company(FMT) [8]. One prototype166 MHz 300 kW circulator will be delivered from FMT in June 2021; and the 500 MHz 150 kW circulators will be delivered from FMT in Oct. 2021.

Both 300 kW water loads (see Fig. 8) consist of six 50 kW resister absorbers and only differ in the outputs. The low power measurement shows a very good VSWR of 1.05 for both loads. And during the high-power test up to CW 260 kW, the temperature rise was normal, no obvious deterioration of the VSWR was found after improvement based on the first prototype test. A control system was integrated to read the power absorbed by the water and provide interlocks for low cooling water flow rate, high temperature difference between each absorber and water leakage and so on.

(a) (b)

Figure 8: Water loads under high-power tests: (a)500 MHz 300 kW; (b)166 MHz 300 kW.

Fundamental Power Couplers

Both 166 MHz and 500 MHz 300 kW prototype FPCs have been developed successfully at IHEP during the HEPS-TF [9, 10] and BEPCII [11] period respectively. Now the formals are under fabrication in IHEP workshop and will be delivered in this year.

FINAL REMARKS

The layout of the HPRF systems for the HEPS has been designed. Most prototypes of key components have been designed, fabricated and tested successfully. The construction of the HPRF systems for HEPS is underway.

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