ULTRAHIGH VACUUM SYSTEM OF THE SSRF

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Abstract

The design of SSRF ultrahigh vacuum (UHV) system faces two special problems, the high dynamic gas load and the high power load. Several methods were adopted to solve above problems both in the system design and in the structural design of vacuum components. In R&D, five key components of the vacuum system were properly selected as the research projects. The key fabricating techniques were settled. All prototypes could meet the design targets. The model of the storage ring vacuum system consisting of the prototypes could reach a ultimate pressure of 9×10^{-9} Pa.

1 INTRODUCTION

The Shanghai Synchrotron Radiation Facility (SSRF) is a new third-generation light source composed of a linac, a total energy booster, an electron storage ring, and experimental facilities. Its heart is a 3.5 GeV storage ring with 396m in circumference.

The ultrahigh vacuum (UHV) system is an important composition of the facility, which provides the necessary operating environment for the circulating electron beam. The storage ring vacuum system has 20 similar cells based on the lattice design. Every cell can be isolated from other parts with gate valves to form an independent vacuum system. The storage ring vacuum system is composed of 40 6-meter long bending chambers, 20 straight chambers, 15 insertion device (ID) chambers and other chambers connected by RF shielded bellows. The vacuum evacuating and measuring equipment, photon absorbers and other system equipments such as beam diagnostic instruments are installed on the vacuum chambers. Fig. 1 shows one standard cell vacuum system.

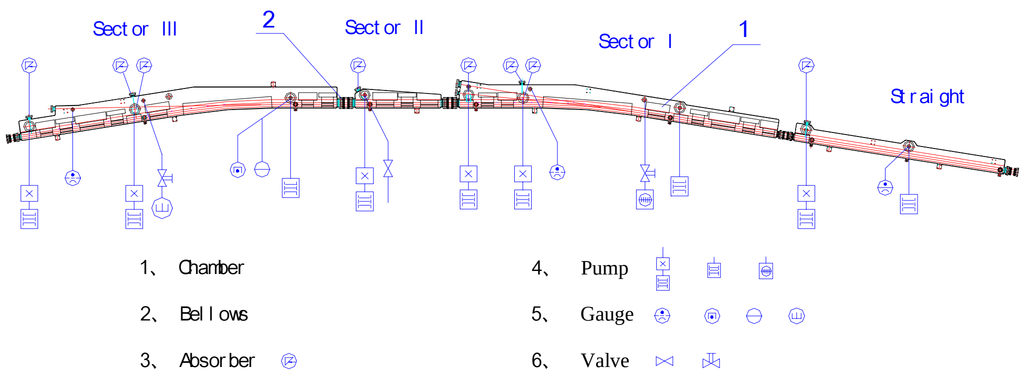

Figure 1: One standard cell vacuum system of SSRF

2 REQUIREMENTS FOR THE VACUUM SYSTEM

In SSRF storage ring, the high-energy electron beam will generate intense synchrotron light. This light will irradiate the vacuum system directly and form two loads to the system. The first is the large desorption gas load stimulated from the vacuum chamber wall by synchrotron light, which is ten to thousand times higher than the thermal outgassing load. This gas load will cause the increase of the pressure. The second is the synchrotron radiation (SR) power load with power density about 1kW/m along the ring. Most of the power will be absorbed in the vacuum system. The two loads make the electron storage ring UHV system face more austere problems than other accelerator vacuum systems.

The physical requirements of electron beam and the experimental requirements of users decide the basic requirements for the UHV system: (1) Maintain a dynamic pressure of less than 1.3×10^{-7} Pa to meet the requirements of beam lifetime of more than 20 hours. (2) Have enough ability to absorb and transfer the power load so that the SR power can be effectively dealt with. (3) The broad band impedance should be low enough to avoid the beam instability and decrease the HOM loss. (4) Have enough mechanical stability to meet the requirements of monitoring the beam position and extracting the SR precisely.

3 DESIGN OF THE UHV SYSTEM

In SSRF, the antechamber structure[1] design is adopted. The chamber is composed of beam chamber and pumping chamber separated by a 12 mm high slot. The SR will pass through the slot to the pumping chamber, most of which will be stopped by the water-cooled photon absorbers in it. The extracted SR, collimated by two neighbouring absorbers, will be drawn into the front end. Discrete pumps with large pumping speed will be installed just below the absorbers to effectively pump the photon stimulated desorption (PSD) gas load.

When the SSRF storage ring operates at 3.5 GeV and 300 mA, the electron beam will radiate 8.48×10^{20} photons per second. According to the operating datum of similar facilities, a PSD coefficient of 3×10^{-6} molecules/photon[2] is adopted. The total gas load in the ring is 1.33×10^{-5} Pa.m^3/s. To achieve a dynamic pressure of 1.3×10^{-7} Pa, the total effective pumping speed should be more than 1×10^2 m^3/s. The main pump is the combination of the titanium sublimation pump (TSP) and the sputter ion pump (SIP). According to the layout of photon absorbers and other correlative components, there are 160 TSPs and 200 SIPs in the ring. The total nominal pumping speed is 3×10^2 m^3/s. The vacuum system can be baked at 150℃ in situ. During start-up and baking, movable turbo-molecular pumps will be used to pump the system. There are 45 vacuum gauges and 12 RGAs to monitor the vacuum state of the system.

4 DEVELOPMENT OF THE VACUUM COMPONENTS

In R&D, five key components of the vacuum system are selected as the research projects. These components are designed, fabricated and tested according to the engineering requirements to assure that both the scheme selection and the structural design is reasonable and the machining techniques are feasible.

4.1 Aluminum alloy vacuum chamber

As the direct exterior environment of the electron beam, the chamber should not only meet the requirements of UHV but also match with other equipments and have high position accuracy and high stability. The exterior structure, at the location of the magnets, was designed to match with the magnets. Above and below the chamber, there are cooling channels on the surface. ConFlat® type sealing structure with Al-SS transition material was used for most of the flanges. The BPM flanges are sealed by Helicoflex® gaskets for high position precision. Helicoil® screws were used inside the screw holes of aluminum body. The 6m-long chamber prototype made of aluminium alloy 5083-H321 was formed by numerical control machining and TIG welding. In R&D, several techniques and approaches were adopted to solve the key problems in chamber fabrication — machining distortion, welding distortion, leakage and surface contamination. The fabrication of the chamber is successfully finished. The total planeness of the chamber is 0.23 mm. The maximum transverse error in horizontal plane is 1.4 mm. The average inner surface roughness is 0.4 μm. The surface outgassing rate is 4.1×10^{-10} Pa.m^3/s/m^2. The chamber prototype pumped by the combination of three SIPs and one TSP can reach a pressure of 5.7×10^{-9} Pa. The chamber prototype is shown in Fig. 2.

4.2 Photon absorber

Figure 2: The prototype of the vacuum chamber

As the collimator for the extracted SR and the absorber for the unused SR power, the SSRF storage ring photon absorbers need absorb 90% of the total radiated power. The absorber, 1.6 m from the light source and with 140 mm in width, will intercept a total power of about 4 kW. Its power density in normal incidence is 83.1 W/mm^2. The absorber is designed with such a structure that the SR will incident upon the absorbing surface with a grazing angle of 10^0, which dilute the power density to 14.4 W/mm^2. The absorber body is made of OFHC and the cooling channels are machined. In the region of high power density, thermocouple is set to monitor the temperature of the absorber body. By calculation, we get a satisfactory result that the maximum temperature is 160 ℃ when the storage ring is in full current. This temperature is well below the maximum allowable one. There are two types of absorbers. One is the horizontal absorber mounted from top surface of the chamber as

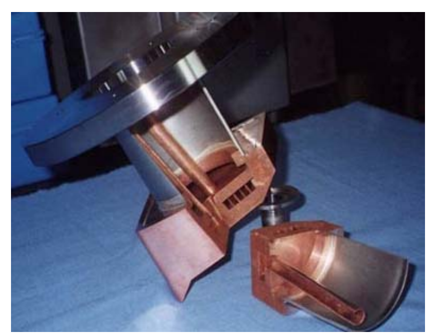

Figure 3: Structure of the horizontal absorber

shown in Fig. 3. The other is the vertical absorber at the lateral of the chamber. Several fabrication techniques have been used to the two absorber prototypes including numerical control machining, electric spark machining, electron beam welding, multiple brazing and so on. The R & D stage for absorbers have been finished with satisfactory. The PSD performance was tested for the horizontal absorber prototype in collaboration with KEK • PF in Japan. The results showed that its dynamic desorption could fulfil the design requirements.

4.3 RF shielded bellows assembly

The RF shielded bellows, located at the longitudinal joint between two vacuum chambers, can fit the vacuum chamber during installation, compensate the machining and installing error, absorb the expansion and the compression of the chamber caused by temperature change. Because the ordinary bellows has large impedance, which will cause beam instability and HOM loss inside it, the movable RF shielding structure should be settled inside it. A new type of double-finger RF shielding structure[3], as shown in Fig. 4, is adopted in SSRF storage ring. The peripheral spring fingers made of Inconel 625 press the Be-Cu contact fingers tightly on the beam tube. Properly select the force to keep a good electrical contact between the contact fingers and the beam tube when the bellows moves in certain range. Welded bellows are used outside the assembly. Both sides of the bellows have cooling channels. In R & D, two typical bellows are successfully designed and fabricated. Their maximum longitudinal moving range is –33 mm～+10 mm. The allowable transverse offset is ±2mm. The contact force between the contact fingers and the beam tube is about 120 g/finger. All the data can fulfill the storage ring requirements. The high power load test for the bellows prototype was conducted in cooperation with KEK in Japan. The results confirmed that the bellows could be used in SSRF.

Figure 4: Bellows and its inner RF shielding structure

4.4 Pump

The structural features of the SSRF vacuum system determine that most of the PSD gas load will concentrate around the photon absorbers. In these areas, large pumps should be installed to pump out the dynamic gas load effectively. In storage ring, the pump volume is limited by space. A new TSP with large pumping speed and small volume is developed. The diameter of the pump is 202 mm and the height is 270 mm. A cylindrical liner, made from folded stainless steel thin plate, is installed inside the pump. The inner area of the pump is thus increased to nearly three times larger than the normal cylinder. The Ti sticking area is thus increased consumedly. In test, the TSP can reach a pumping speed of 2500 l/s for H_2 and 1300 l/s for CO. The ultimate pressure of testing system pumped by TSP and a 200 l/s SIP reaches 1×10^{-9}Pa.

5 MODEL OF UHV SYSTEM

A model of SSRF UHV system is constructed using the component prototypes. Its performance has been tested. After being baked at 150℃ for 48 hours, the system reaches an ultimate pressure of 9×10^{-9} Pa. The main residual gas is hydrogen, which is about 90% of the total residual gas. No contamination in spectrum can be seen. The test results show that the vacuum prototypes have been reasonably designed, their surface states are good and the seals are reliable.

6 CONCLUSIONS

The initial design of the SSRF UHV system has been completed. During the R&D stage, five key components are reasonably selected as the research projects. Structural design, technical research, fabrication and performance test are all conducted according to the real engineering requirements. All prototypes can meet the design targets and reach the same level as the similar facilities. The key techniques and procedures necessary for the construction of SSRF vacuum system have been mastered. The mass producing condition for engineering stage is possessed.

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