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PARTICLE-FREE ENGINEERING IN SHINE SUPERCONDUCTING LINAC VACUUM SYSTEM

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Abstract

The Shanghai high-repetition-rate XFEL and extreme light facility (SHINE) is under design and construction. The linac of SHINE facility is superconducting accelerating structures of high gradients, whose performance is closely related to the cleanliness of superconducting cavities. Therefore, the beam line vacuum system has extremely high requirement for particle free to avoid particles down to submicrometric scale. To control particle contamination, particle-free environment has been built for cavity string assembly and other beam line vacuum components installation, clean assembly criterion has been established. Furthermore, the particle generation of vacuum components (valve, pump, etc.) has been studied. Moreover, dedicated equipment and component (slow pumping & slow venting system, non-contact RF shielding bellow) have been developed for particle-free vacuum system.

INTRODUCTION

SHINE is a new hard-XFEL facility under construction in China, which is designed to accelerate electron beams to 8 GeV by 600 1.3 GHz 9-cell cavities working in continuous wave mode, and the cavities is installed in 75 cryomodules [1]. Cleanliness is essential in the preparation of field emission free, high gradient, low loss superconducting cavities [2], therefore, not only the cavities but also the beamline vacuum components adjacent to cryomodules has extremely high cleanness requirement. The design, fabrication, cleaning, assembly, testing process of these components must be followed the cleanliness requirement.

In SHINE linac, the total length of particle-free zone is 1.2 km, including cryomodules and room temperature (RT) beamline. For cryomodules, the vertical test of single cavity, cavity string assembly and cryomodule horizontal test are all carried out in SHINE. For RT beamline vacuum components, most pre-cleaning is performed at supplies. For integrated equipment like collimators, profile monitors wire scanners, e.g., the particle-free assembly is carried out at supplies. For standard components like vacuum gauges, valves, pumps, the cleaning before final assembly is carried out in SHINE.

INFRASTRUCTURES, EQUIPMENTS AND TECHNOLOGIES

A 400 m^2 cleanroom have been built in 2019 for SHINE superconducting cavity string assembly, which has 300 m^2 ISO 4 class area and 100 m^2 ISO 5 class area.(Fig. 1 top).

The cleanroom includes ultrasonic cleaning, high press rinsing (HPR), cavity drying areas, and the cavity string assembly area is capable for up to 8 persons to assembly 2 cavity strings at the same time (Fig. 1 bottom).

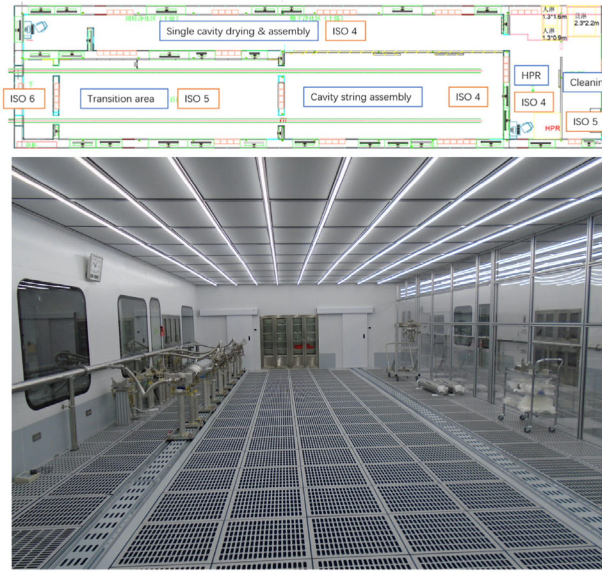

Figure 1: ISO 4 class cleanroom for cavity string assembly.

Various moveable laminar flow booths have been used for particle-free operation at cryomodule horizontal test, cavity vertical test, beam line vacuum components, e.g. High Efficiency Particulate Air (HEPA) filter was used in all of these booths, so as to obtain a local cleanness higher than

Figure 2: Moveable laminar flow booths for local particle-free assembly.

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than ISO 5 class, while the direction of laminar flow of each booth is various according on specific working conditions (Fig. 2).

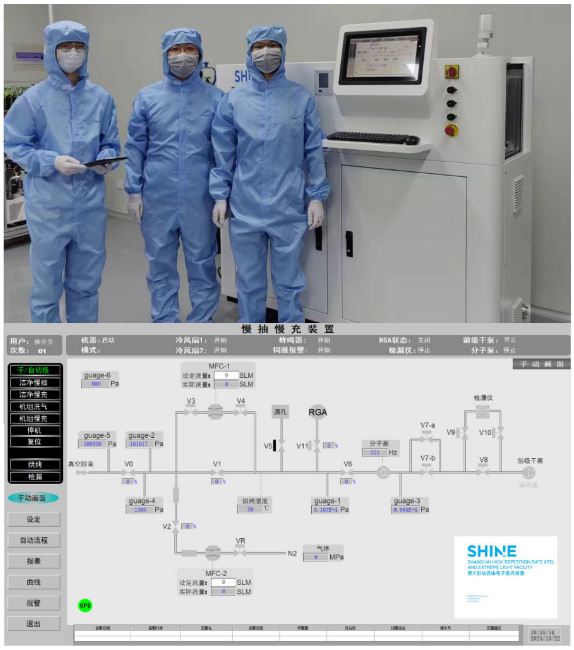

Figure 3: Dedicated slow pumping, slow venting system.

Several kinds of full-automatic slow pumping and slow venting (SPSV) systems have been developed for particle-free vacuum system (Fig. 3). The mass flow rate in pumping and venting procedures could be set down to 0.2 SLM, so as to avoid turbulent flow and reduce the probability of contamination and particulates transporting in vacuum system.

Figure 4: Ion pump assembled in ISO 4 clean room.

More than 200 ion pumps will be installed onto the particle-free vacuum system, which were cleaned and assembled follow the particle-free criterion, the body of pump was rinsed in flowing super purified water, and baked out in ISO 6 class cleanroom, after that purified nitrogen gas blowing cleaning were carried out before final assembly in ISO 4 class cleanroom (Fig. 4).

Non-evaporable getter pumps are used at the RT section adjacent to cryomodule, hence the cleanness of getter pump after activation is much concerned. Cleanness tests of getter pump was performed in two ways, one is in-vacuum monitoring, and the other is nitrogen gas blowing at atmosphere.

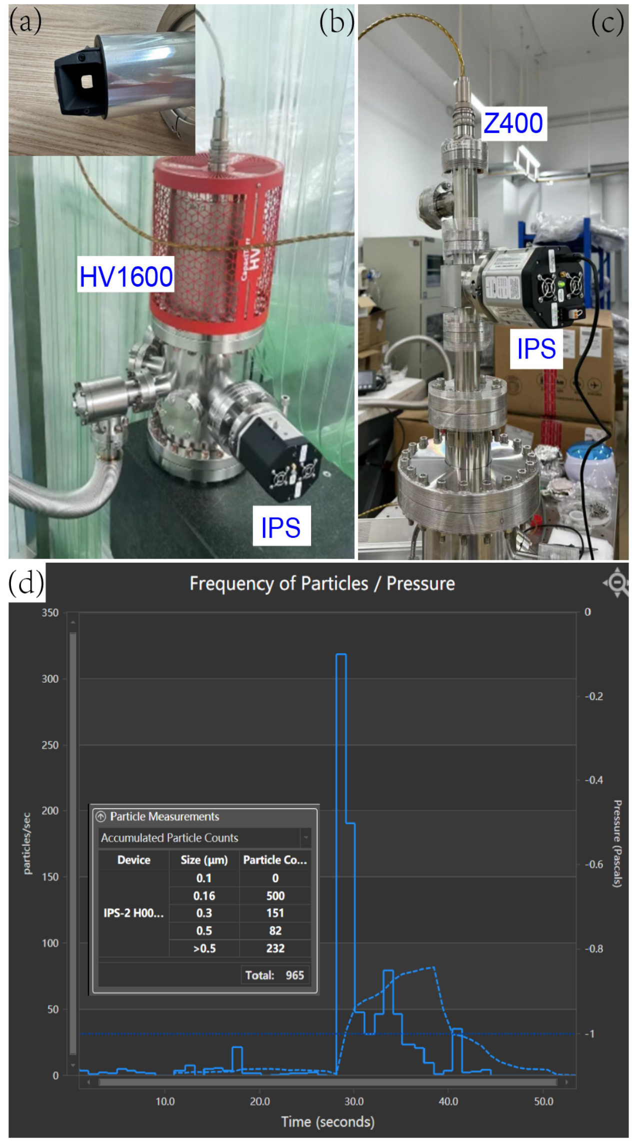

Figure 5: (a) In-vacuum sensor of IPS, (b) Saes HV 1600 getter pump particle test, (c) Saes Z400 getter pump particle test, (d) particle count of IPS.

To monitor the particle generated in the process of getter pump activation, a in-vacuum particle counter (In-line particle sensor, IPS, CyberOptics) was used, which can measure particles greater than 0.16 µm size, with less than 5 false counts per hour. However, the inlet of the measuring area of IPS is smaller than 1 cm^2, showed in Fig. 5a, the possibility of particle in vacuum transport to measuring area is quite low, to monitoring the particles, IPS has been installed right under a getter pump (Saes Z400), the setup is showed in Fig. 5c. During the process of degas of Z400, the voltage range is 0 to 5 V, 1×10^{-3} Pa, no particle was detected. Afterwards, the voltage was raised to 15 V gradually, while the pressure was 5×10^{-4} Pa, few particle was detected until the voltage and current of Z400 reached 14.9 V and 3.9 A, respectively. The count of particle (size 0.16, 0.3, 0.5, >0.5 µm) is several hundred per minute, showed in Fig. 5d. The number of counts lasted for 5 minutes, and dropped to 300 pc/minute.

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In another in-vacuum test of Saes HV1600 getter pump, the measuring area of IPS is not right under the pump, therefore nearly no particle was detected.

Another HV1600 getter pump have been installed in a pump station for the cavity string vacuum at the cryomodule horizontal test stand. After 3 times activation and 2 months operation at 200 °C, the NEG pump was dismounted from the pump station and blowed using purified nitrogen gas at 4 bar, the particle was monitored by airborne particle counter (28.3 L/min), nearly 700 pc/10 s of 0.3 µm and 200 pc/10 s of 0.5 µm was detected, no more particle was detected after 5 minute blowing.

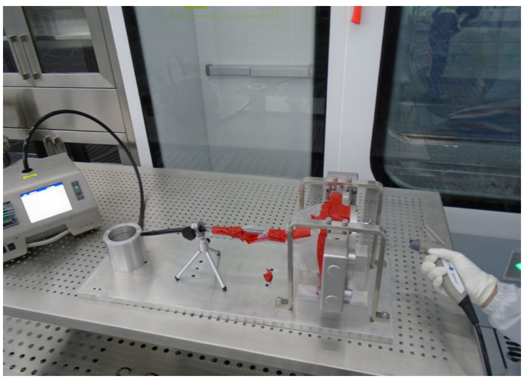

Figure 6: Particle test of valve open/close action.

The valves used in SHINE beamline vacuum is all-metal, therefore, valve open/close action always generate particles. Tests have been carried out for angle valves and gate valves (Fig. 6), the results show that every single open/close action could generate dozens of particles at 0.3 and 0.5 µm size.

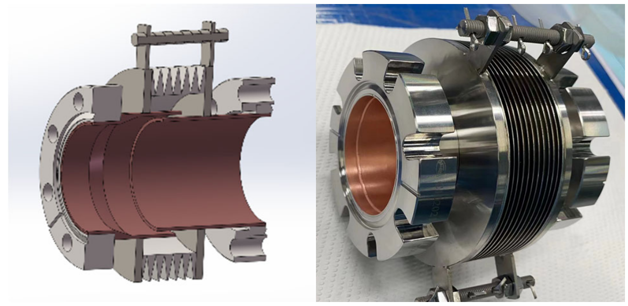

Figure 7: Non-contact RF shielding bellow.

To avoid friction between metals which could generate the large number of particles, a non-contact type RF shielding bellow design is adopted in room temperature beamline vacuum (Fig. 7). This RF bellow has 2 copper tube nested inside and out, with a radial direction offset 2 mm.

CONCLUSION

Due to the adoption of superconducting RF technology the SHINE project is facing with new challenges in UHV engineering. Infrastructures, technologies and procedures for particle-free vacuum, low temperature vacuum and other related vacuum system are established and developed to support the SHINE project construction.

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