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COMMISSIONING OF RF SYSTEM OF THE 200 MeV PROTON CYCLOTRON

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Abstract

The SC200 superconducting accelerator which is designed for proton therapy is currently under construction. The RF (Radio Frequency) system has been designed and constructed as a subsystem of the SC200. To verify the stability of the RF system, a high-power feeding test was performed for the cavity. This paper mainly reports on the overview of RF systems and the preliminary high-power commissioning, as well as the problems found and improvements made during the commissioning process. The results show that the RF system has initially achieved the designed goal, and each loop (amplitude, tuning, phase) can work effectively. The cavity can operate in a ~50 kW continuous wave state. Next, the formal RF conditioning will be carried out after the complete assembly of cyclotron, so as to confirm the cavity can run smoothly under 80 kW, which is part of the whole commissioning process.

INTRODUCTION

The 200 MeV isochronous Superconducting Cyclotron (SC200), which is an international joint research project, is currently under construction. The radio frequency (RF) system, as the significant component of the accelerator, is designed to provide a specific frequency of electric field for the protons and maintain the stability of the acceleration voltage. The cavities were located at valleys of the magnet in Figure1. The RF cavity is designed into double cavities, with second harmonic acceleration, a resonant frequency of 91.5 MHz, feeding power at 80 kW, and 60kV (Center)~120 kV (Extraction) accelerating voltage [1-3].

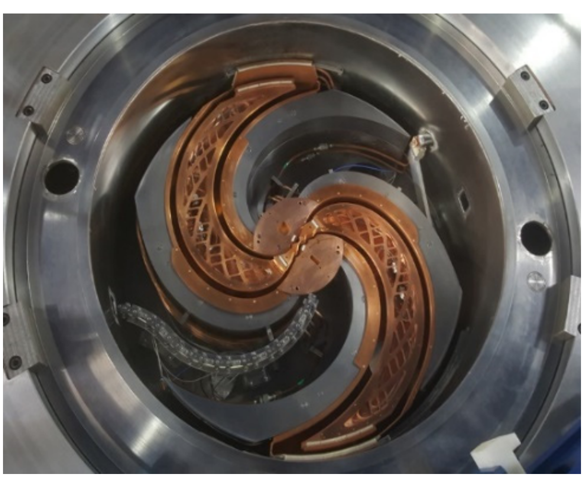

Figure 1: Assembled RF cavity in valleys.

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To verify the stability of the RF system, a high-power commissioning has been performed for the cavity. The overview of the preliminary high-power commissioning is introduced in this paper, as well as the current status of RF conditioning. Some issues have been found in the high-power test, and the related solutions were developed for RF system. The formal RF conditioning will be carried out after the complete assembly of cyclotron in future work.

HIGH-POWER TEST FOR RF SYSTEM

A high-power (~50 kW) test has been made for the prototype SC200 cyclotron. The main components of SC 200 are assembled as shown in Figure 2. Both ion source and superconducting coil were able to work properly. A cold test (test without power) has been done before the high-power test in Table 1. The main parameters of RF cavity meet design requirements. The current of superconducting coil was 140 A and the magnetic field strength of the magnet was ~3 T in the high-power test. The strong field contributes to reduce the risk of multipactor in cavity [4]. So that higher power can be fed into the cavity. The cooling water around RF cavity ensures a low temperature for RF cavity. The pressure of cooling water is 5.5 MPa.

Figure 2: SC200 cyclotron host for the high-power test.

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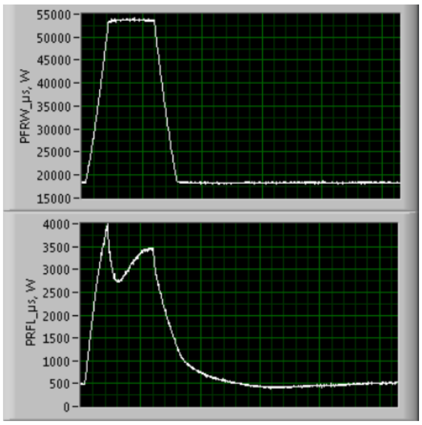
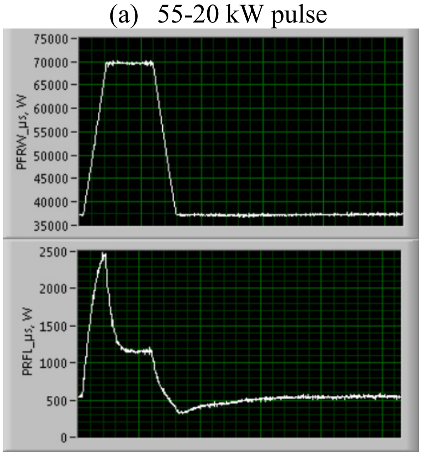
Table 1: Main Parameters of Test for RF System

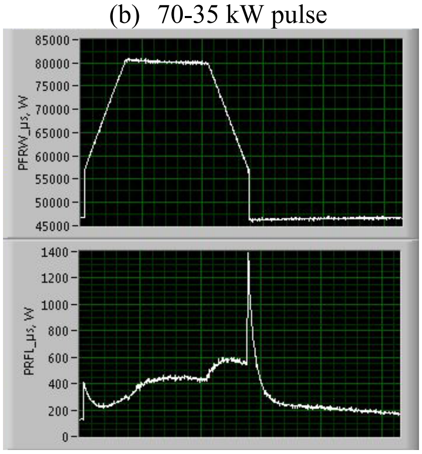
Parameters	Value	Test type
Frequency	91.5 MHz	Cold test
Q factor unloaded	5200	Cold test
Coupling	S_{11} <-30 dB	Cold test
Vacuum degree	1×10^{-4} Pa	High-power test
Cooling water pressure	5.5 MPa	High-power test



(a) 55-20 kW pulse



(b) 70-35 kW pulse



(c) 80-45 kW pulse

Figure 3: RF conditioning with different pulse wave.

(top picture: forward pulse wave power; bottom picture: reflection power)

The Low Level RF (LLRF) control system adjusts the tuners in real-time to keep the resonant frequency at 91.5 MHz. It also controls the power amplifier to feed power to RF cavity. RF conditioning consists of pulse wave mode and continuous wave mode. RF conditioning with different pulse wave is shown in Figure 3. After increasing power gradually and long-term RF conditioning, the performance of the cavity is getting better and better. Finally, the cavity could be fed ~50 kW continuous wave power without reflection after 4 weeks RF conditioning. And each loop (amplitude, tuning, phase) of RF system can work effectively. The temperature rise of RF cavity is no more than 30 ℃ due to good cooling effect. And the frequency deviation caused by temperature rise is estimated no more than -40 kHz based on previous multi analysis [5]. It Meets tuning design.

THE PROBLEMS AND IMPROVEMENTS FOR THE TEST

The high-power test stopped after running ～30 hours at ~50 kW continuous wave power. The RF window was broken down due to multipactor, which lead the failure of vacuum environment of cyclotron host. The multipactor which mainly occurred on the interface of inner conductor of RF window, caused breakdown on the ceramics and outer conductor, as shown in Figure 4. And some solutions will be made to improve the RF window. The main method is to improve the gas circulation between the RF window and the vacuum chamber of cyclotron host. Several venting holes were designed on outer conductor of the coupling (connect with RF window closely) as shown in Figure 5 (a). Four symmetrical venting gaps were also punched on inner conductor of the coupling in Figure 5 (b). A pumping hole were also added on the outer conductor to improve the vacuum of RF window. Besides, extending the time and reducing the gradient of RF conditioning to reduce surface gas of materials may be another solution. Making sure the vacuum degree of cyclotron is better than 10-4 Pa during RF operation. Last but on least, a cooling system will be designed for the RF window to reduce the temperature influence due to multipactor heat.

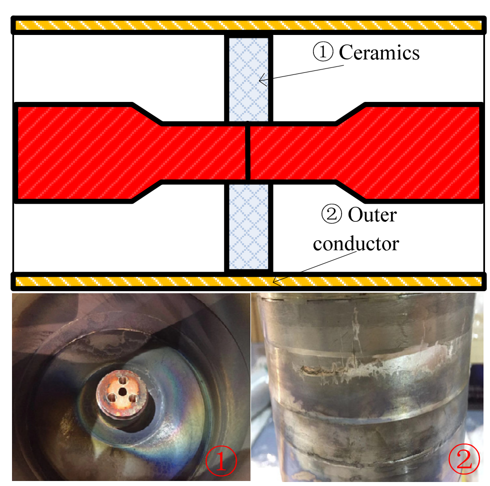


Figure 4: Breakdown of RF window.

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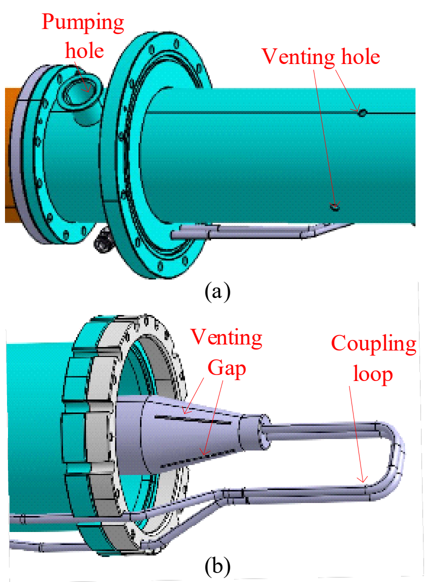

Figure 5: Pumping hole and venting hole (or gap) on the coupling.

What's more, the Stem of RF cavity was damaged after checking. The plugs and the braid made RF contact finger were burned due to bad electrical contact in Figure 6. There is a possible solution to improve the electrical contact between Stem and cavity. The braid contact finger which is soft may bring bad electrical contact. But the copper ring has a good elasticity. The braid will be changed to copper rings to contact Stem with RF cavity point by point in Figure 7. The copper rings are installed around the groove of Stem.

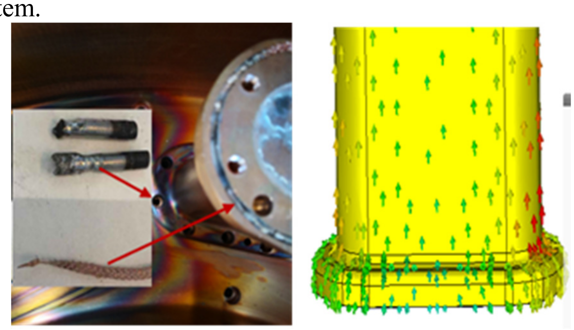

Figure 6: Damaged stem of RF cavity.

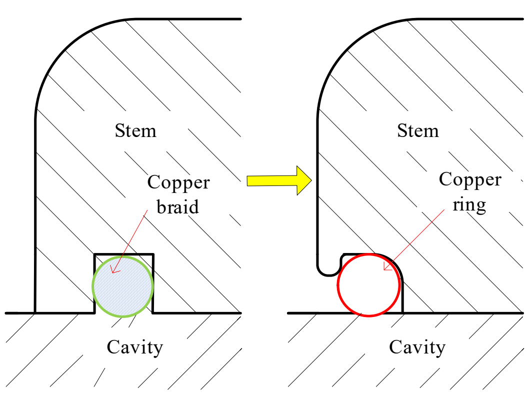

Figure 7: Optimization for the Stem.

CONCLUSION AND FUTURE WORK

A high-power feeding test has been performed for RF system of SC200. The main parameters of RF cavity meet design requirements. Both ion source and superconducting coil were able to work properly. The cavity could be fed ~50 kW continuous wave power without reflection after 4 weeks RF conditioning. And each loop (amplitude, tuning, phase) of RF system can work effectively. The RF window was broken down with >50 kW continuous wave power due to multipactor, but solutions has been made to improve it. In the future, the formal RF conditioning will be carried out after the complete assembly of cyclotron, so as to confirm the cavity can run smoothly under 80 kW.

ACKNOLODGEMENT

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