DESIGN AND COMMISSIONING OF RF SYSTEM FOR SC200 CYCLO-TRON

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Abstract The SC200 proton therapy superconducting cyclotron is currently under construction by ASIPP (Hefei, China) and JINR (Dubna, Russia). The RF (Radio Frequency) system which provides an accelerating electric field for the particles, has been designed and tested in a high-power commissioning. The RF system consists of RF cavity, Low-level RF control system, RF source, transmission network and so on. The main performances of RF cavity meet design and use requirements in the cold test. The RF cavity achieved an unload Q factor of 5200 at the resonant frequency of 91.5 MHz, 65kV (Center)~115 kV (Extraction) accelerating voltage and coupling state of S11 <-30 dB. The low-level RF (LLRF) system has been tested with an amplitude stability of <0.2% and a phase stability of < 0.1 degree in the high-power commissioning. What's more, the cavity has already operated in a ~50 kW continuous wave state after 4 weeks RF conditioning. Some risks have been exposed at higher power test, but related solutions and improvements have been developed. In future work, the target of RF system is effective operation under the overall assembly of cyclotron after further optimization and RF conditioning.

Introduction

The RF system which provides an accelerating electric field for the particles, has been designed and tested in a high-power commissioning. The key components of RF system are Low-level RF control system, RF source, transmission network, which will be discussed in following paragraphs. [1~2] A high-power commissioning has been performed for the cavity. RF conditioning contributes to improve the performance RF cavity, so as to achieve high power feeding in cavity. Temperature record and X-ray calibration have also made for RF cavity to verify its performance. More-over, some improvements have been done for cavity to solve related problems.

Design of RF system

The RF cavity consists of Dee, Liner, Stems, Trimmers and coupling looping. The layout of RF cavity is shown in Fig. 1. Some optimizations have been made on the cavity based on the original physical model. Moreover, a cold (no feeding power) test has been made on a mock-up cavity to verify its main parameters. [3] The test results are shown in Table 1.

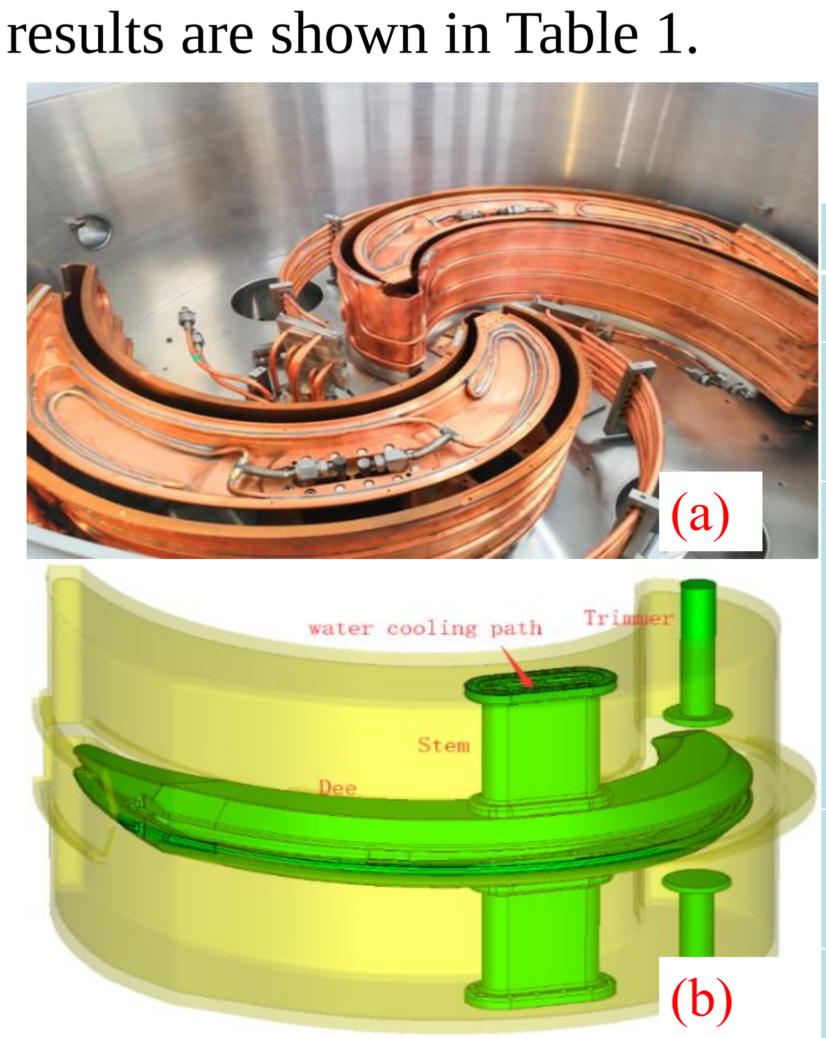

Figure 1: Layout of RF cavity.

Table 1: Main parameters of RF cavity in cold test vs. design.

Parameters	Design	Cold test
Frequency	91.5 MHz	91.5 MHz
Tuning range	±100kHZ	91.4MHz +180kHz
Accelerating voltage	60 kV (Center)~120 kV (Extraction)	65kV (Center)~115kV (Extraction)
Unload Q factor	5500	5200
Coupling state	S_{11} <-30 dB	S_{11} <-30 dB

The RF source is a Solid Amplifier with full power of 120kW at frequency 91.5±1 MHz. The Low-level RF control system (LLRF) controls the Solid Amplifier to feed power to RF cavity. The adjustment process is implemented by three main loops. The amplitude loop compensates fast distortions for amplifier with a stability<0.2%. The phase loop keeps the phase of cavity field to the desired value with a stability < 0.1°.

The commissioning of high-power test and improvements

A high-power test has been made for the prototype SC200 cyclotron. We increased the pulse wave power gradually under good coupling state for RF conditioning in Fig. 2. The temperature of cavity was recorded for frequency deviation analysis. A X-ray measurement has been finished to calibrate the accelerating voltage in cavity. The high-power test stopped after running ～30 hours at ~50 kW continuous wave power due to the breakdown of RF window. Some improvements were made for cavity to solve the problem. [4] The structure of RF window was optimized to reduce the risk of multipactor. Venting holes (or gaps) were designed to improve the vacuum degree in RF window. Cooling pipes were arranged on RF window and coupling to reduce thermal stress as shown in Fig. 3.

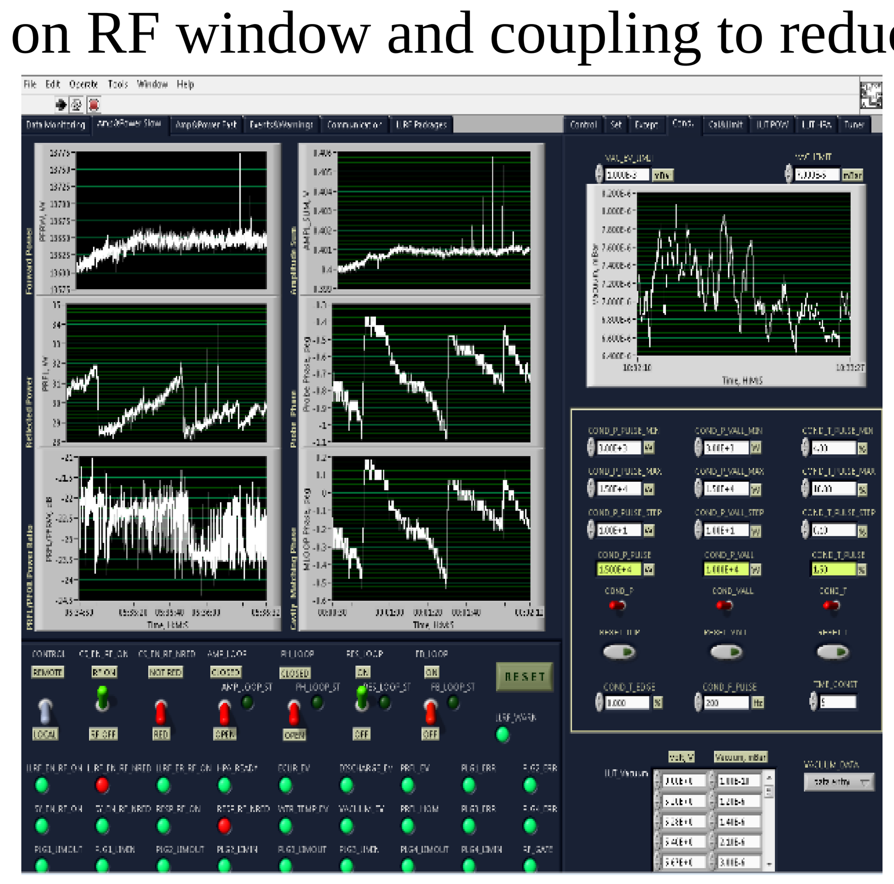

Figure 2: The interface of LLRF system for RF conditioning.

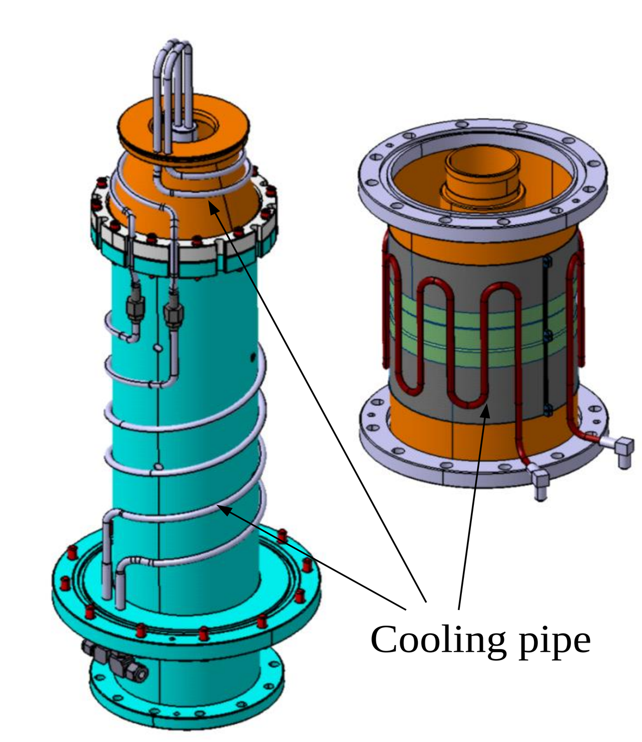

Figure 3: Cooling pipes on RF window and coupling.

We improved the electrical contact situation on Dee and Stem. The copper rings were used on Stem instead of the original copper braid. The "L" type RF contact fingers which have better condition within 2.5mm are used be-tween two Dees as shown in Fig. 4. Last but not least, the water-cooling paths were modified on cavity. We designed semicircular groove for cooling pipes on Dee to increase heat dissipation area as shown in Fig. 5. A three-way connector was added to fix pipe on Dee.

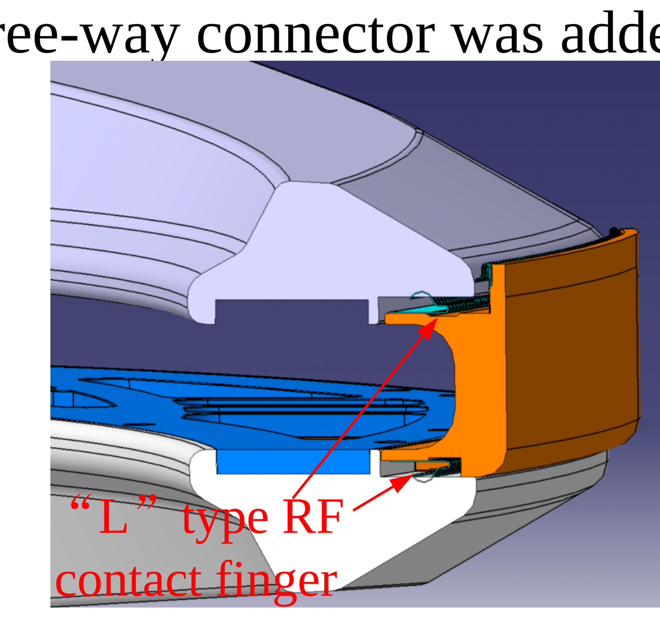

Figure 4: "L" type RF contact finger for Dee

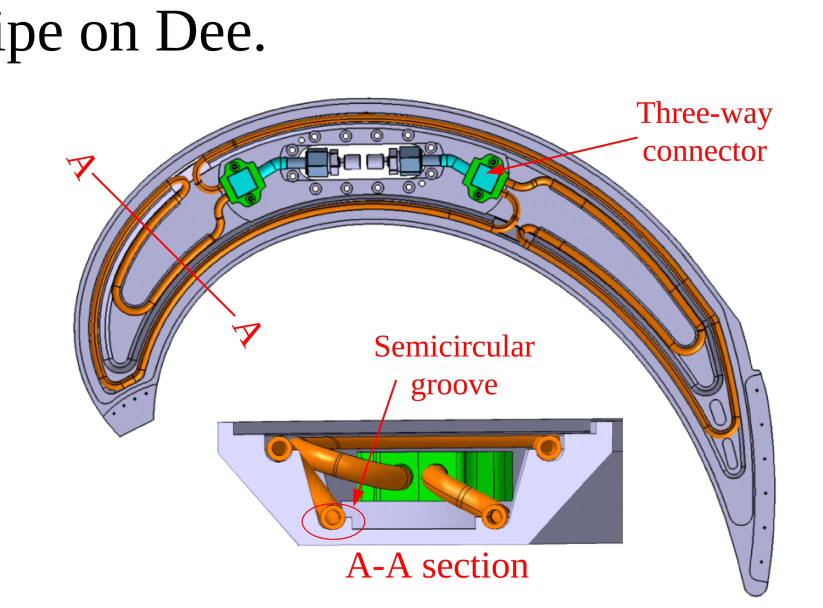

Figure 5: Water cooling optimization on Dee.

Conclusion

The RF system of SC 200 mainly consists of RF cavity, Low-level RF control system, RF source and so on. The main parameters of RF cavity have been verified in a cold test. The LLRF system has been tested with an amplitude stability of <0.2% and a phase stability of < 0.1 degree. The cavity could be fed ~50 kW continuous wave power without reflection after 4 weeks of RF conditioning. The improvements which are mainly about RF window, electrical contact and cooling system have been made to solve related problems.

[1] G. Chen et al., in Proc. IPAC'18, Vancouver, Canada, pp. 3616-3618.

[2] G. A. Karamysheva et al., in Proc. Cyclotrons'16, Zurich, Switzerland, Sep. 2016, pp. 371-373

[3] G. Chen et al., in Proc. Cyclotrons'16, Zurich, Switzerland, pp. 208-211.

[4] G. Chen†, G. Liu, et al., in：IPAC'19, melbourne convention & exhibition centre, Australia, 2019.