R&D OF IMP SUPERCONDUCTING HWR FOR CHINA ADS

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Abstract

The R&D program of IMP superconducting HWR is based on the China ADS, The aim is to build and test a HWR prototype on December 2012. We have designed a 162.5 MHz β=0.09 half-wave resonator (HWR), and a copper HWR has been fabricated in January 2012. The fabrication of a Nb HWR will be completed by September 2012, and the fabrication of a slow tuner and a high power coupler for this HWR will be completed then. In this poster, we present the HWR electromagnetic design, mechanical design, fabrication arts, copper HWR RF test result, the design of the slow tuner and the power coupler.

INTRODUCTION

At present, many energy researchers agree that nuclear energy is the best way to solve the issue of an energy shortage. In order to apply nuclear energy in a safe and clear way, the accelerator and nuclear scientists obtained a reasonable way to apply nuclear energy and dispose the nuclear wastes, this is an accelerator-driven system (ADS). IMP and IHEP are developing a high-intensity CW H- ion linac for China ADS (Accelerator Driven Sub-critical System), The main design parameters of linac are listed in Table1 [1]. Two injectors are being constructed by IMP and IHEP to demonstrate the most critical R＆D issue related to the front-end of a CW high-power and proton linac. InjectorⅠ chose Superconducting spoke cavity to accelerate H- from 3.2MeV to10MeV，which is being constructed by IHEP. InjectⅡ chose Superconducting Half-wave Resonator to accelerate H- from 2.1MeV to10MeV, which is being constructed by IMP. HWR is a well built superconducting cavity international, there are many labs in the word have designed and constructed HWR cavities.

Table 1: China ADS Linac Main Design Parameters

Parameters	Value	Unit
Particle	Proton	
Frequency	162.5/325/650	MHz
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
Duty factor	100	%

ELECTROMAGNETIC DESIGN

The design of the HWR consists in reaching a reasonable compromise between optimal electromagnetic performances, acceptable mechanical characteristics, and ease of fabricating and preparation [2]. The first step in this HWR design is to optimize the RF properties of the HWR.

The goal of the RF properties is to get a lower heat load and a higher accelerating gradient, which are determined by a higher R/Q0 (R is the shunt impedance and Q0 is the quality factor) and lower peak surface fields (Bpk/Eacc and Epk/Eacc). There are four electron beams welding in the cavity high magnetic region when welding our HWR, and we can't grinding this region, so the performance limitation in the HWR is the thermal-magnetic quench, which leads us to put more care to minimize Bpk/Eacc.

RF Optimization

The most important design parameters to optimize were: Bpk/Eacc, Epk/Eacc, R/Q0 and G [3]. A selected number of cavity geometry parameters were used during this optimization. They are shown on Fig. 1.

In order to optimize the HWR geometry parameters, CST-MWS is used to conduct the RF simulation. Starting from a initial HWR model showed in Fig. 1 and varying the geometry parameters one at a time we were able to establish the general dependence of the important design parameters on the geometry parameters, Fig. 2 shows the quantitative dependence in %.

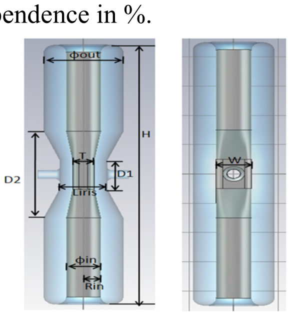

Figure 1: Parameters of the cavity geometry used in the RF optimization.

We notice that the design parameters to optimize are more sensitive to the parameters, namely, Rout, Rin, T, Liris, W and Rblend2. Increasing the HWR outer conductor radius (Rout), a significant improvement in all parameters of interest. Beyond 92 mm we begin to sacrifice real-estate gradient. We choose Rout as 92 mm. By decreasing the inner conductor radius (Rin) while

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keeping the same outer conductor at 92 mm, R/Q0 goes up, but Emax/Eacc also goes up when Rin is smaller than 40 mm. We choose Rin as 40 mm. By Varying the W and Rblend2, Emax/Eacc is smallest when W is 90 mm and Rblend2 is 17 mm, while other RF parameters change a little. We choose W as 90 and Rblend2 as 15.

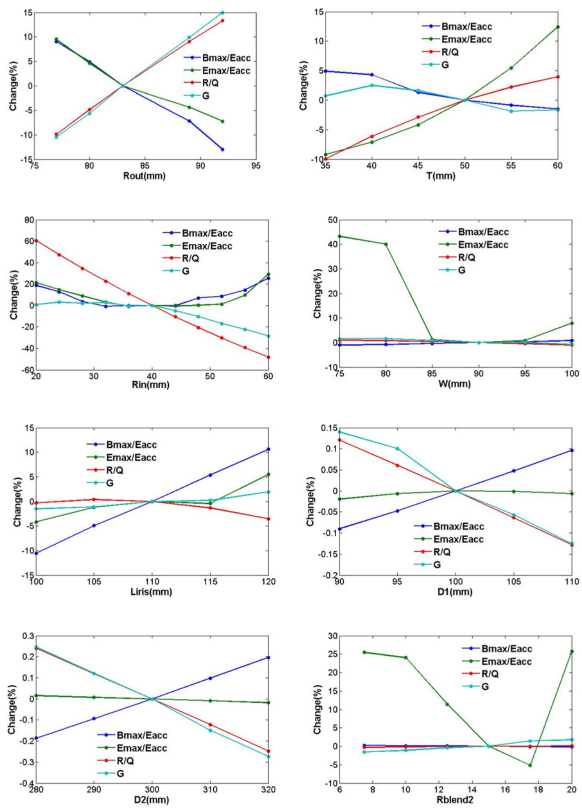

Figure 2: Quantitative dependence of the design parameters in % as function of the geometry parameters.

Optimized Geometry Parameters and RF Parameters

Table 2: Final design parameters of the IMP HWR

Parameters	Value	Unit
Frequency	162.5	MHz
β opt	0.095	
Uacc	0.78	MV
Epeak	25	MV/m
Bpeak	50	mT
R/Q0	148	Ω
G=Rs*Q0	28.5	Ω
Q0(4.4)	6.7E8	

TUNER AND COUPLER

The working of IMP HWR tuner bases on the principle of a slight elastic deformation by applying a pushing and pulling force at the beam tubes. This causes a change in the gap width and the accompanying variation of capacity finally results in a frequency shift. The Diagram of the HWR tuner is shown in Fig. 3. The rf-response of the cavity was simulated with ANSYS and CST-MWS. The tuning sensitivity of the HWR is 179.9 kHz/mm. The spring constant of the HWR is 2.178kN/mm.

The HWR assembled with coupler and tuner is shown in Fig 3. The HWR coupler is a 50-ohm coaxial line with Single ceramic window. This coupler was designed to run at 15 kW power. The parameters of the coupler antenna are in table 3. These parameters are simulated by CST-MWS.

Table 3: Parameters of the Coupler Antenna

Port diameter	Antenna diameter	Antenna length	Qext
40mm	17.4mm	43mm	6.88E5

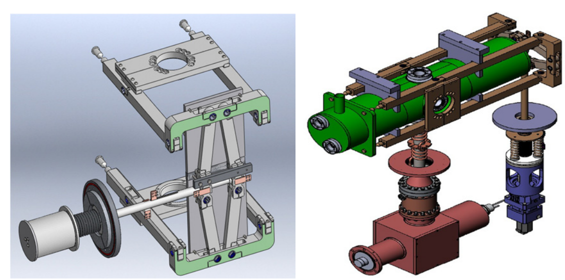

Figure 3: Tuner and HWR assembled with coupler and tuner.

HWR COPPER MODEL

A HWR copper model was built at IMP to test the HWR fabrication procedure and to study the low-level RF behavior of the resonator. Fig. 4 is the HWR copper model. We got the biggest input RF power is 563 W during the RF measurement. The biggest voltage between two gaps is about 60 kV. The RF measurement and CST-MWS simulation result are shown in table 4. The frequency simulation result is a little smaller than the measurement result. The Q0 simulation result is about 20% higher than the RF measurement result.

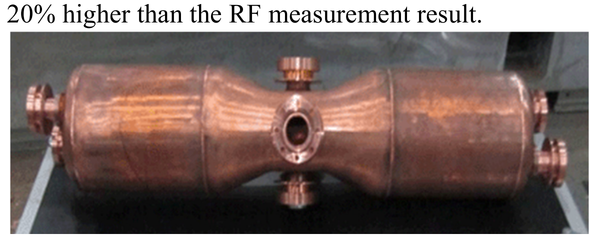

Figure 4: HWR copper model.

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Table 4: Copper Model RF Measurement and CST-MWS Simulation Result

Parameters	Measurement	Simulation
Frequency	162.6MHz	162.18MHz
Q0	7040	8561

NIOBIUM HWR FABRICATION

The IMP HWR mainly consists of three parts, inner conductor, outer conductor and top/bottom covers. The inner conductor and outer conductor were fabricated from niobium sheets by deep drawing and electron-beam welding. The top/bottom covers were fabricated from niobium sheets by deep drawing. The beam pipes, coupler pipes and process ports pipes were fabricated form niobium rods by machining.

Figure 5: The main parts of IMP HWR.

The residual resistance ratio (RRR) of niobium sheets and rods is 250. The main parts of IMP HWR are shown in Fig 5. Particularly critical are the four electron- beam welds between inner conductor, outer conductor and top/bottom covers, which are made from the outside, and a reliable method for obtaining a smooth weld seam at the inner cavity surface was required. We assembled the three parts for HWR frequency measurement before final welding, as shown in Fig 6.

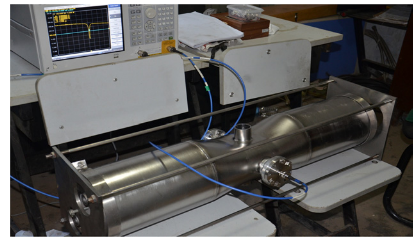

Figure 6: Frequency measurement before final welding.

SUMMARY

The HWR introduced in this paper can be used to accelerate proton from 2.1 MeV to 10 MeV. The fabrication of the HWR will be completed by September 2012. We expect to vertical test this HWR on December 2012.

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