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PROTOTYPING PROGRESS OF SSR1 SINGLE SPOKE RESONATOR FOR RAON

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Abstract

We report the current status of prototyping of the SSR1 cavity ($\beta = 0.3$ and $f = 325$ MHz) for Korean heavy ion accelerator RAON. Simulation results on target frequency for vertical test of the cavity prototype are presented. Clamp-up tests for the cavity assembly are in progress.

INTRODUCTION

The RAON, an advanced heavy ion accelerator for basic sciences and multiple applications, is under construction in Daejeon, South Korea [1]. Based on the on-going technical designs, the prototyping for four different types of superconducting cavities (QWR [2], HWR [3], SSR1 [4], and SSR2) is in progress. In particular, the SSR1 cavities before the SSR2 section can reaccelerate the stable isotope heavy ion beams from the HWR cavities ($\beta = 0.12$) after the QWR section to higher energy ($\beta = 0.3$) with the resonant frequency of 325 MHz.

After completing the fabrication of the SSR1 cavity prototype, it will be qualified through vertical tests. Therefore, the target frequency considering the resonant frequency shifts by the followings: final electron beam welding (EBW) of an outer conductor with end walls, buffered chemical polishing (BCP), evacuation for ultra-high vacuum of the cavity, cooling to the temperature of 4 K and 2 K, and liquid helium (LHe) pressure acting on the cavity at the temperature should be determined before final trimming of the outer conductor and then EBW with end walls. The electromagnetic (EM) analyses with mechanical simulations will be given in the next section. In addition, the present status of clamp-up tests performing before final EBW is briefly introduced.

DETERMINATION OF TARGET FREQUENCY FOR VERTICAL TEST

The CST MWS and the CST MPhysics codes were utilized for predicting the target frequency of the SSR1 prototype. Figure 1 shows the variation of resonant frequency with respect to the width of the cylindrical outer conductor. Both sides of the outer conductor are simultaneously trimmed by the same length as shown in the inset. The positive sign at horizontal axis represents the decreasing width of the outer conductor and the negative one does the increasing that. Zero distance means the original design value of the outer conductor width. The slope was calculated to be -407.5 kHz/mm. It can be applied to the estimation of the resonant frequency shift by final EBW. Considering the shrinkage of 0.6 mm

at each side in the case of niobium (Nb), the frequency shift by the EBW is -244.5 kHz.

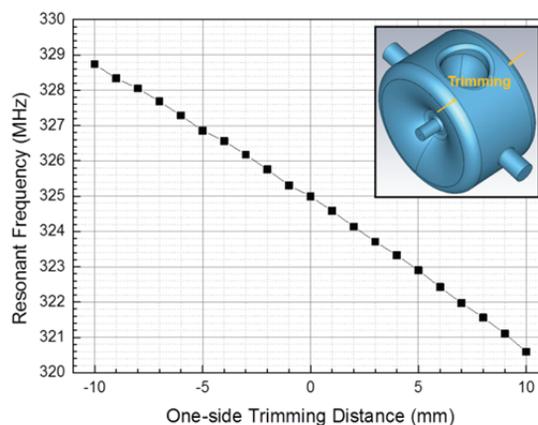


Figure 1: Variation of resonant frequency with changing the width of the outer conductor of the SSR1 cavity.

Figure 2 shows the variation of resonant frequency with respect to the BCP depth. Zero depth also means the original cavity design. The inset shows the simulation results in the narrower depth range. In both cases, it is expected that some fluctuations are caused by the limited mesh numbers. The frequency shift per unit depth calculated from linear fits of the data points is approximately $-150 \sim -202$ Hz/ μm . For determining the target frequency, -150 Hz/ μm was used.

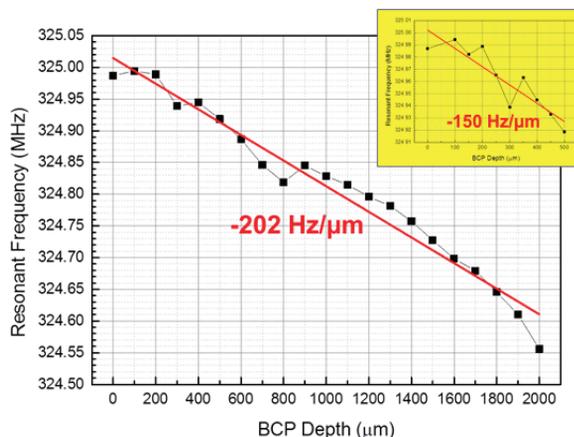


Figure 2: Variation of resonant frequency with changing the BCP depth of the SSR1 cavity.

The resonant frequency shift by vacuum in the cavity maintained during the vertical test should be considered. Figure 3(a) shows the deformation by pressure acting on the cavity due to the vacuum of the cavity inside. The pressure of 1 bar was assumed and the resultant maximum

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displacement near the one-side beam port was estimated to be ~ 5.3 mm. As a boundary condition for the vertical test, the other-side beam port was fixed, which was applied to all simulations in this paper. The distribution of the electric field in the cavity obtained by EM simulation is shown in the Fig. 3(b). The resonant frequency estimated from the deformed cavity is ~ 327.18 MHz, which is ~ 2.2 -MHz larger than that of the originally designed cavity.

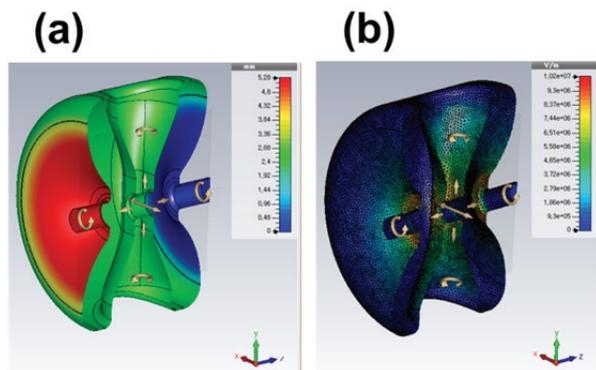


Figure 3: (a) SSR1 cavity deformed by vacuum pressure and (b) its electric field distribution.

The SSR1 superconducting cavity will be operated with LHe at the temperature of 2 K. Thus, we should also consider the deformation of the cavity by the cool-down. Figure 4(a) shows uniform temperature distribution in the cavity when it was cooled down to 2 K. The maximum displacement at the one-side end wall due to the temperature is estimated to be ~ 0.9 mm as shown in Fig. 4(b). From the EM analysis, the resonant frequency shift was calculated to be $+981$ kHz.

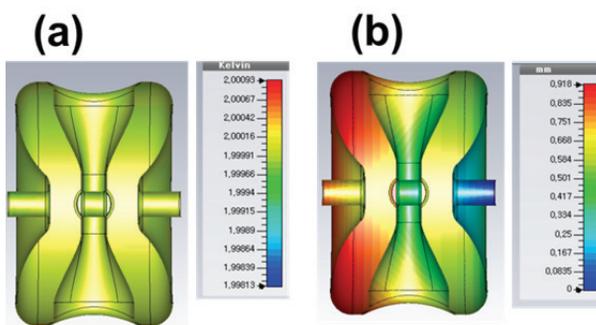


Figure 4: (a) temperature distribution in the SSR1 cavity by cool-down to 2 K and (b) the cavity deformation due to the temperature.

For the vertical test at 2 K, first, the SSR1 cavity is cooled down to 4 K by introducing the LHe to helium (He) space in a cryostat, and then it can be done to 2 K by pumping out the He vapor remaining in the He space. Thus, we can consider two types of frequency shifts with opposite sign at each temperature. Figure 5(a) shows the cavity deformed by the temperature of 4 K. The maximum displacement by the LHe pressure at the cavity outside (1.3 bar) is estimated to be ~ 6.9 mm at the one-

side end wall, which results in the frequency shift of $+512.41$ kHz. However, as shown in Fig. 5(b), the 2-K LHe pressure at the cavity outside decreases to 0.03 bar by pumping out the He vapor (maximum displacement of ~ 0.16 mm) and it can lead to the frequency shift with negative sign (approximately -2.37 MHz).

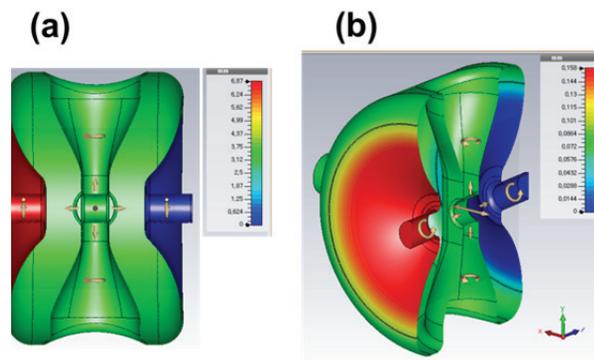


Figure 5: SSR1 cavity deformation at (a) 4 K and (b) 2 K.

Therefore, the target frequency before final welding of the outer conductor with end walls was determined to be 323.919 MHz due to the above steps. The summary on the target frequency determination is shown in Table. 1.

Table 1: Target Frequency for Vertical Test of the SSR1 Cavity Prototype

Frequency Shift	Value (MHz)
Resonant frequency	324.987
External pressure at 2 K (0.03 bar)	324.987 (-2.36541)
External pressure at 4 K (1.3 bar)	327.352 (+0.51241)
Cool-down (room temperature \rightarrow 2 K)	326.84 (+0.981)
Vacuum (1 bar)	325.859 (+2.189)
BCP (150 μ m)	323.67 (-0.0048)
Welding shrinkage (0.6 mm)	323.675 (-0.2445)
Clamp-up state (target frequency)	323.919

CLAMP-UP TEST FOR SSR1 CAVITY PROTOTYPE ASSEMBLY

The SSR1 cavity components such as a spoke, an outer conductor, end walls, and beam ports were fabricated by pressing, deep drawing, machining, BCP, and EBW using Nb plates. All components except for the outer conductor and the end walls were assembled and welded. The clamp-up tests for the cavity prototype have been performed (Fig. 6). The resonant frequency of the prototype has been measured with trimming the outer conductor whose width has additional margin and the measurement results have been compared with simulation ones. The fabrication errors will make discrepancy in desired resonant frequency. Especially, the frequency is very sensitive to several design parameters of the spoke cavity, for instance, the radius of the outer conductor, R_{cavity} . Therefore, strict tolerance management when fabricating the cavity components is required. The identical clamp-up conditions such as the same tension at both end walls should be also satisfied. After final trimming of the outer conductor for the target frequency, final EBW will be followed and vertical tests for the SSR1 prototype at the temperature of 2 K will be performed in near future.

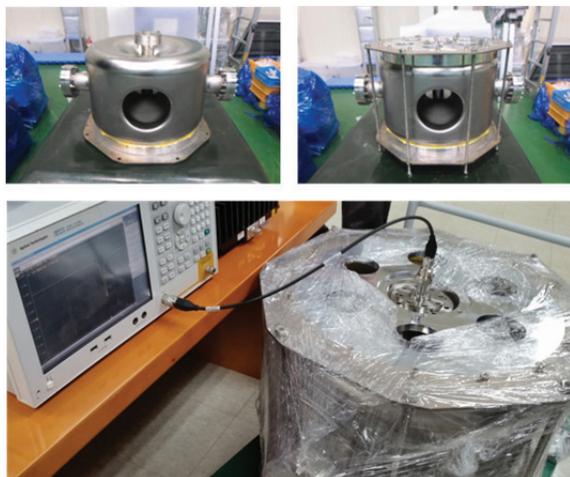


Figure 6: Clamp-up test for the SSR1 cavity prototype assembly.

CONCLUSION

The target frequency for vertical test of the SSR1 prototype was predicted through EM & mechanical analyses. The fabrication of the prototype components was done and the clamp-up tests with resonant frequency measurement are in progress. The vertical tests at 4 K and 2 K for the cavity prototype are planned.

ACKNOWLEDGMENT

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