PROTOTYPING OF TEM-LIKE MODE RESONATORS IN THE RAON

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Abstract

Preliminary electro-magnetic designs of TEM-like mode resonators (a quarter wave resonator, a half wave resonator, two single spoke resonators) are accomplished for the superconducting linear accelerator in the RAON [1]. Resonant cavities are numerically optimized using a CST MWS code to obtain higher E-field gradient along the beam line in conditions of the peak E-field and B-field is less than 30MV/m, 60mT respectively. Prototyping of a quarter wave resonator of optimum beta 0.047 is in progress to analyze resonant frequency shifting by tolerances in fabrication process and external perturbations. It will be compared with expected one using computational codes.

INTRODUCTION

Quarter Wave Resonators (QWRs) are adopted in the superconducting linac section for the 0.047 lowest optimum beta. QWR is like a simple cylinder of 220mm outer diameter and 905mm length with a conical stem, donut-shaped drift tubes, rounded upper/lower ends. The performance of cavity is estimated and optimized by using CST MWS code. In the optimization, the fabrication cost, symmetry of transversal field around drift tubes, minimization of peak E-field/B-field are mainly concerned. The geometric parameters and Electromagnetic performance are shown in the table 1.

Table 1: QWR Parameters

Parameters	Unit	Value
Total height	mm	905
Outer diameter	mm	220
Diameters of the conical stem	mm	40/80
Accelerating voltage	MV	0.9
Accelerating gradient	MV/m	5.2
Peak electric field	MV/m	30
Peak magnetic field	mT	51
R/Q	Ω	470
Unloaded Q	10^9	2.1

MULTIPACTOR

Multipacting phenomenon is one of main issues in designing of RF structures [2, 3]. If emitted electrons hit one or two surfaces periodically due to resonance with the applied RF and the secondary emission yield is higher than one, the number of electrons can be increased geometrically. These electrons can degrade the RF devices by absorbing electromagnetic energy and raising the temperature of the surface by hitting.

Applied RF levels of multipactors in QWR and power coupler are predicted by using CST PIC code with the secondary emission yield(SEY) of a 300℃ baked Niobium.

Multipactors in QWR

Several peaks are shown in the Figure 1 of multipacting factors of 4 RF periods. The most serious multipactor occurs around the upper end of QWR at 1/8 of the accelerating gradient (5.2MV/m). These estimated multipacting barriers will be compared with the results of Q-factor measurements.

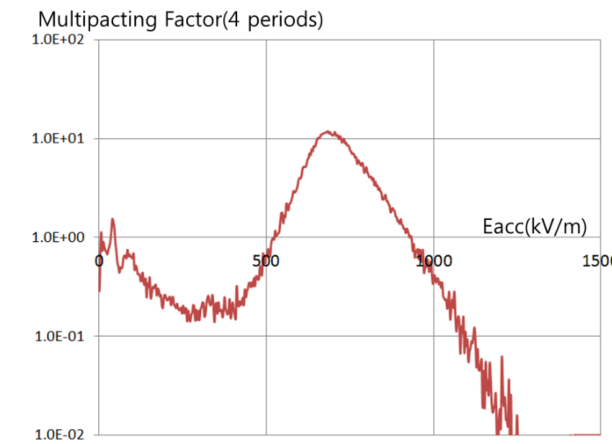

Figure 1: Predicted multipactors in QWR (CST PIC code)

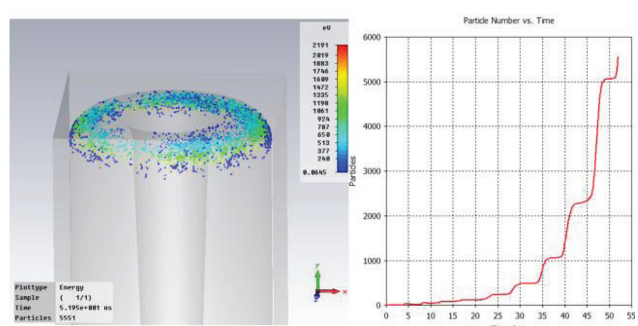

Figure 2: A Multipactor in the upper end of QWR @ Eacc= 0.5MV/m (CST PIC code)

Multipactors in RF Power Coupler

In the case of coaxial RF power coupler, the RF power levels of multipactors are proportional to the 4th power of the multiplication of the distance between two conductors and the RF frequency as shown in Figure 3. And the RF power level of MPs with standing wave is one 4th of the level of MPs with travelling wave [3].

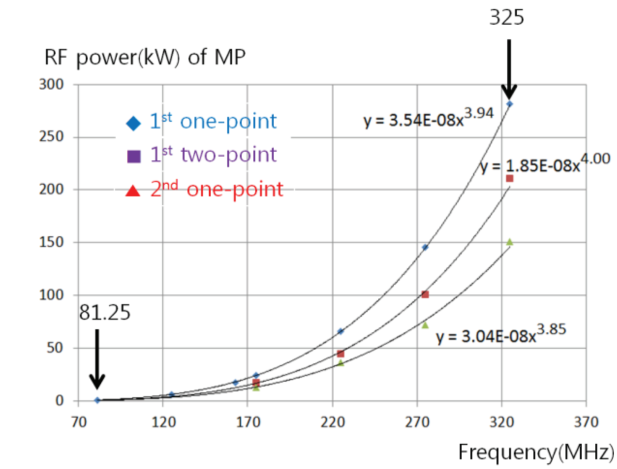

Figure 3: Multipacting RF levels of variable frequency in 100Ω power couplers (Outer diameter: 80mm).

As the minimum required RF power for operation of SSR2 cavity is about 10kW (the beam current is about 1mA), the lowest MP barrier must be larger than 20kW with a safety factor. The multipactors of a 325MHz 100Ω RF coupler are predicted by using CST PIC code with the SEY of 300℃ baked Niobium as shown in the Figure 4. No multipactor appears in the 100 Ω power coupler of 80mm outer diameter when the applied 325MHz RF power is less than 30kW.

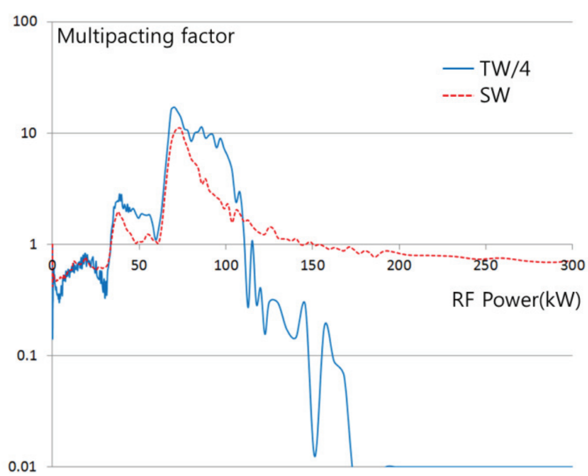

Figure 4: Multipacting RF levels of 325MHz 100Ω power couplers (Outer diameter: 80mm).

For driving QWR cavities, a 70Ω coupler is chosen to reduce the RF surface loss. The multipactor is checked by computational simulation on couplers of variable outer diameters as shown in the Table 2. If the outer diameter is less than 40mm, multipactor is not found at any RF level. And also the multipactor in case of standing wave does not appear in CST PIC simulations.

Table 2: Multipacting RF levels of 81.25MHz 70 Ω power couplers (Travelling wave case)

Outer Diameters(mm)	RF power level of Multipactors(watt)
80	880
60	340
50	190
40	-

MECHANICAL DETUNINGS

As the loaded Q-factors of superconducting resonators are larger than 10^6, -3dB bandwidth of 81.25MHz QWR cavity is about 40Hz. Tuners will be installed in QWRs to match the resonance frequency with applied RF frequency, but it is not easy to follow up the fast detuning due to the microphonics. So, the minimizing of frequency sensitivity on the external pressure is a main process of optimization [4]. Predicted detunings due to the tolerances of fabrication and the frequency sensitivities to mechanical deformings are estimated by using CST MWS code and ANSYS Mechanical v.14.5 with HFSS v.15 as shown in the Figure 5. The predicted detunings and sensitivities of the bare cavity are shown in the Table 3.

Table 3: Detunings and Frequency sensitivities of QWR cavity

Detunings	Value
Length of upper part (from beam port)	-67kHz/mm
Length of lower part (from beam port)	+1.3kHz/mm
Chemical etching (around nose)	+20kHz/mm
Chemical etching (others)	-8.6kHz/mm
External pressure	-46Hz/kPa
Cool down(293K to 2K)	+200kHz
Lorentz force	-1.7Hz/(MV/m)^2

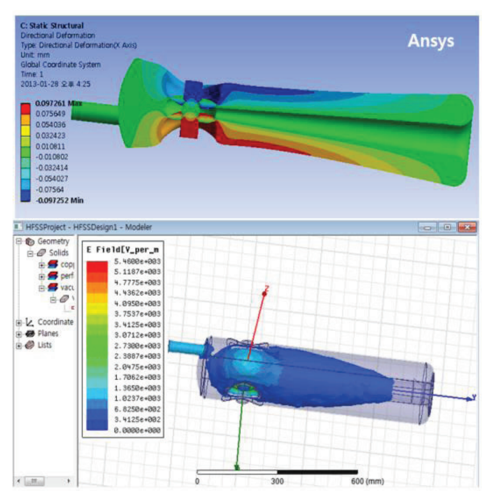

Figure 5: Predicted deforming (upper) and resonant frequency detuning (lower)

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In the model for simulations of frequency sensitivities, only beam pipes are fixed without additional coupled points and stiffening structures. The resonant frequency shift due to external pressure can be reduced less than 10Hz/kPa if additional stiffeners like simple thin disks are attached on the upper end of QWR [5].

PROTOTYPING OF QWR CAVITY

QWR Cavity is fabricated by EB welding of hydro-formed 3mm Niobium sheets, drift tube and 4 additional ports without bottom flanges. Two ports in the lower end are added for RF power/pickup coupling. The other two ports are installed for evacuation and high pressure rinsing.

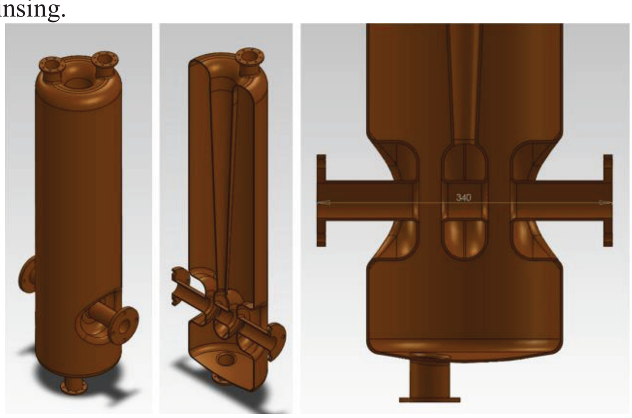

Figure 6: Engineering drawing of naked QWR cavity

CONCLUSION

The preliminary EM optimization, prediction of multipactors and mechanical analysis of QWR cavity is finished. Naked QWR cavities will be fabricated from oxygen-free copper, Niobium and tested in a cryostat soon. During the prototyping of QWR cavities, the engineering designs of Helium vessels, tuners, couplers, etc. will be completed.

ACKNOWLEDGEMENT

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