Study on the Beam Acceleration Based on HWR Structure at KOMAC

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1. Introduction

A superconducting accelerator based on half-wave resonator (HWR) is considered to increase the proton energy to 180-MeV after 100-MeV conventional drift-tube linac (DTL) within existing accelerator tunnel at Korea Multi-purpose Accelerator Complex (KOMAC). The operating frequency of the HWR is 350 MHz which is the same with the RFQ and DTL. The maximum peak electric field and peak magnetic field were limited under 35 MV/m and 70 mT respectively [1]. One feature of the designed HWR is that the geometrical beta of the cavity is 0.58 which means the height of the HWR is nearly the same with its diameter, which is one motivation to decide the type of the cryomodule. We considered a cylindrical shape cryomodule as a baseline design for HWR not only because a box type cryomodule has little advantage for KOMAC HWR in the viewpoint of volume, but also because a cylindrical type cryomodule is widely used in superconducting accelerator and we can use the plentiful experience on cylindrical type cryomodule. The overall cryomodule design was based on that of Spallation Neutron Source (SNS). The operating temperature of the HWR is 2 K. There are four HWR cavities in the cryomodule and a normal conducting doublet was chosen as a focusing element located in between cryomodules. The designed cryomodule including two end cans is shown in Fig. 1 [2].

Table 1. Design Parameters of the KOMAC HWR.

Parameter	Unit	Value
Frequency	MHz	350.0
Optimum beta	-	0.64
Geometric beta	-	0.58
Stored energy	J	17.728
Vacc @ β_{opt}	MV	3.336
Eacc	MV/m	7.212
E0	MV/m	8.200
Ep	MV/m	30.252
Bp	mT	64.392
Ep/Eacc	-	4.195
Bp/Eacc	mT/(MV/m)	8.928
R/Q @β_{opt}	ohm	285.2
G @ 20 nΩ	ohm	123.8
Q_0 @ 20 nΩ	-	6.19E+09
Loss @ 20 nΩ	W	6.38
Aperture	mm	35
L_{eff}	m	0.4625

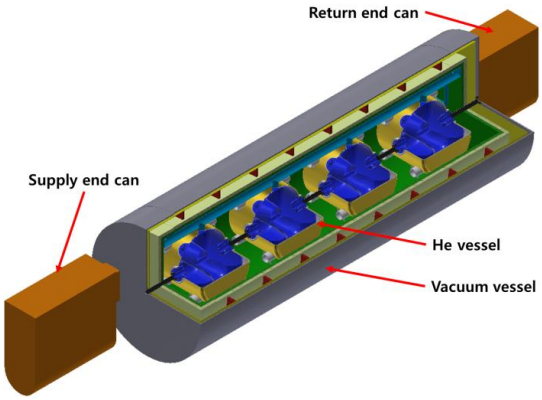

Figure 1: KOMAC HWR Cryomodule.

2. Beam Acceleration with HWR

The acceleration gradient is designed as 7.2 MV/m and 28 HWR cavities are necessary to accelerate the beam from 100 MeV to 180 MeV. A field profile of the HWR cavities is calculated using CST and used as an input to the calculation of the beam acceleration. The field profile used for the calculation is shown in Fig. 2.

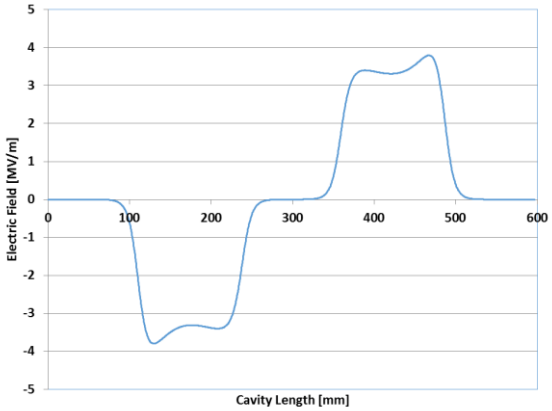

Figure 2: Field Profile of the HWR .

The synchronous phase of the HWR cavity is -30 degrees and the beam phase at the electrical center of each gap of the HWR cavities are calculated and the result is shown in Fig. 3. A basic lattice consists of defocusing quadrupole, four HWR cavities and focusing quadrupole. A matched input beam to the lattice was calculated using TRACE3D. The emittance used for

matched input beam calculation was that of the output beam emittance from the 100-MeV linac. The matched input beam parameter is summarized in Table 2 depending on the quadrupole magnet gradient and the matched beam envelope in the lattice is shown in Fig. 4.

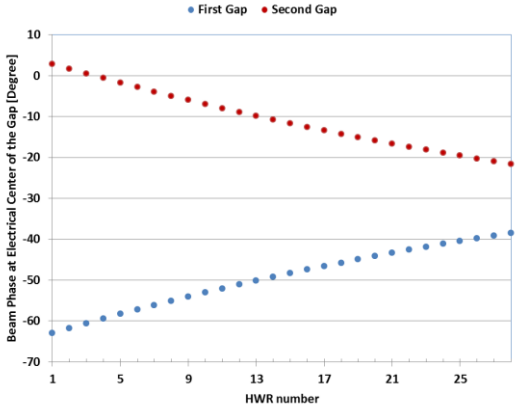

Figure 3: Beam Phase at the Electrical Center of Each Gap.

Table 2. Matched Input Beam Parameter for 9 T/m, 200 mm Quadrupole Doublet.

Parameter	Unit	Value
X Y		
Emittance (unnormal. total)	mm mrad	2.328/2.328
alpha	-	-10.708/10.111
beta	mm/mrad	9.3226/9.1207
Z	-	
Emittance (normal. total)	mm mrad	557.8
alpha	-	0.0285
beta	Deg/keV	0.0197

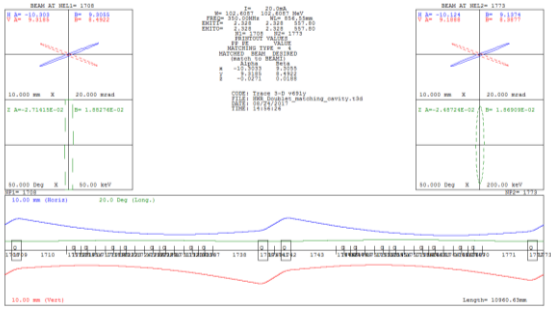

Figure 4: Matched Beam Along the Doublet Lattice.

The matching section between 100-MeV linac and HWR section consists of 8 quadrupole magnets and two bunchers with 3 gaps per each buncher. The matching section parameters with 9 T/m, 200 m quadrupole as a doublet element are summarized in Table 3 and the beam acceleration with 28 HWR cavities is shown in Fig. 5. There are two matching sections along the linac, one for 20-MeV beam matching into 100-MeV linac, the other for 100-MeV beam matching into the HWR section

Table 3. Parameters of the Matching Section

Parameter	Unit	Value
Quadrupole		
Q2	T/m	-11.55
Q2	T/m	-10.36
Q3	T/m	+33.11
Q4	T/m	+16.51
Q5	T/m	-28.01
Q6	T/m	-15.60
Q7	T/m	+41.24
Q8	T/m	+15.11
Buncher		
Gap1	MV	1.89
Gap2	MV	1.76

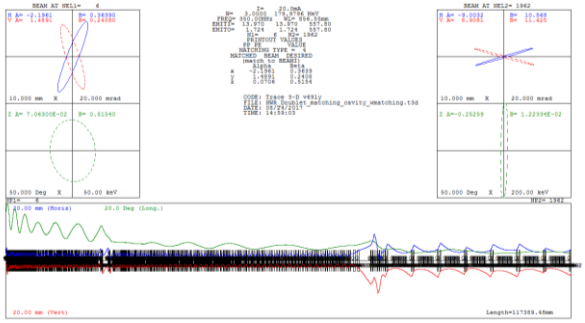

Figure 5: Beam Envelope from 3-MeV to 180-MeV.

3. Conclusions

Matched beam parameters are obtained with four cavities in one cryomodule structure and quadrupole doublet focusing element at the warm sides of the cryomodule. And matching section between 100-MeV linac and downstream HWR cavities was derived with beam envelope calculation. More detailed calculations with particles will be carried out.

ACKNOWLEDGEMENT

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REFERENCES

[1] Han-Sung Kim, et al., Design Study on the Superconducting HWR for Secondary Particle Generation at KOMAC, Proceedings of 18th International Conference on RF Superconductivity, July 17-21, 2017, Lanzhou, China, TUPB049.

[2] Hyeok-Jung Kwon, et al., Preliminary Design on the Cryomodule of the HWR for the Secondary Particle Generation at KOMAC, Proceedings of 18th International Conference on RF Superconductivity, July 17-21, 2017, Lanzhou, China, MOPB049.