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PRELIMINARY DESIGN ON THE CRYOMODULE OF THE HWR FOR THE SECONDARY PARTICLE GENERATION AT KOMAC*

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Abstract

A 100-MeV proton linac based on the radio frequency quadrupole (RFQ) and conventional drift tube linac (DTL) has been operating for user service at KOMAC (Korea Multi-purpose Accelerator Complex). A superconducting linac based on the half-wave resonator (HWR) is studied in order to increase the proton energy from 100 MeV to 160 MeV for the secondary particle generation such as neutron. A cryomodule for the HWR was designed. The operating temperature of the HWR is 2 K. One cryomodule contains four HWR cavities and it didn't have superconducting solenoid because a doublet lattice using normal conducting magnet was considered as focusing elements. A thermal design was conducted and the structure was designed based on the existing well proven technologies. In this paper, the results of the design on the cryomodule for KOMAC HWR are summarized.

INTRODUCTION

A 100-MeV proton linac has been operating for user beam service since 2013. There were 2 beam lines to supply proton to users at 2013, one for 20 MeV beam users and the other for 100 MeV beam users. Both beam lines were general purpose beam line. The third beam line, whose purpose is to produce radioisotope (RI) by using high power proton beam, was constructed in 2015 and is under operation. The fourth beam line, whose purpose is to supply low flux beam to users from the space radiation study and detector development, was constructed in 2016 and is under commissioning [1].

Until now, the major application field of the proton beam is to use the proton beam itself. But it is well-known that energetic proton beam on target can be used to generate secondary particles which have a variety of application fields too. Two kinds of secondary particle are considered to develop secondary particle research platform at KOMAC, one is a Li-8 beam and the other is a neutron. The proposed layout of the secondary particle research facility is shown in Fig. 1. A Li-8 is a beta-emitting radioisotope of which lifetime is 0.8 s. Due to its asymmetry of the angular distribution of the emitting beta-particle, it is used for beta-NMR (Nuclear Magnetic Resonance) as a probe beam. A pulsed neutron generated from the target bombardment by proton beam is a major application field of the high power proton accelerator. KOMAC is going to start a research on the pulsed neutron source based on the proton accelerator by using 100 MeV linac. The research fields include a neutron production target, a short pulse proton beam generation technology, a pulsed neutron beam line. In addition, we considered the development of the superconducting accelerator technology to increase the existing 100 MeV linac. As a first step, we are going to develop a half-wave resonator (HWR) to increase the proton energy from 100 MeV to 180 MeV in the empty space of the KOMAC linac tunnel [2].

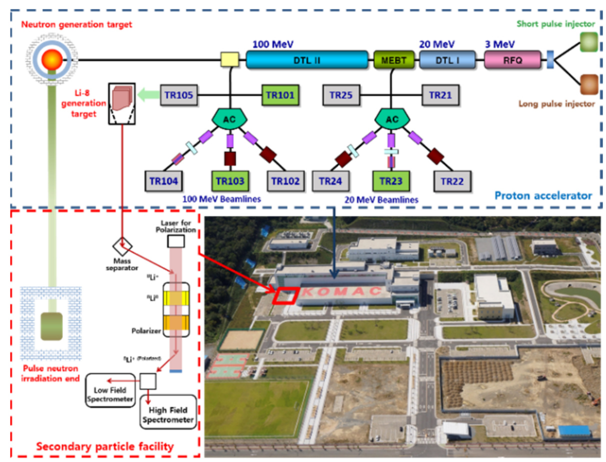

Figure 1: Layout of Secondary Particle Facility.

HALF-WAVE RESONATOR

The operating frequency is 350 MHz which is the same with the RFQ and DTL. The maximum values of the peak electric field and peak magnetic field were limited under 35 MV/m and 70 mT respectively in electromagnetic design stage. One feature of the KOMAC HWR is that the geometrical beta of the cavity is 0.58 which means the height of the HWR is nearly the same with the diameter. The designed HWR is shown in Fig. 2 and the design parameters are summarized in Table 1.

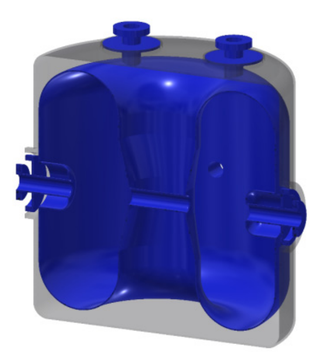

Figure 2: 350 MHz Superconducting half wave resonator for KOMAC proton linac.

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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

CRYOMODULE

One motivation to decide the type of the cryomodule was the feature of the KOMAC HWR which has nearly same dimensions in height and diameter. In this geometry, a cylindrical shape cryomodule can accommodate the HWR cavity as efficient as a box shape with a viewpoint of the cryomodule volume. We considered a cylindrical shape cryomodule as a baseline design for KOMAC HWR cryomodule because a cylindrical type cryomodule are widely used in electron SRF cavities and pulsed proton linac such as SNS [3]. Therefore, we could use their well proven technology and experience.

The overall cryomodule design was based on the SNS cryomodule [3]. 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 between cryomodules. A titanium helium vessel covers the HWR. Magnetic shields are installed outside of the helium vessel and inside of the vacuum vessel to reduce the magnetic field to 15 mG. A 50 K heat shield is installed to reduce the radiation heat load from the vacuum vessel and multi-layer insulations (MLI) are installed both inside and outside the 50 K heat shield. A space frame is used to fix the HWRs and align them. Two end cans, one is supply end can, the other is return end can, are installed at each end of the cryomodule. Two J-T valves are installed at the supply end can and heat exchanger is installed at the return end can. Two phase pipe is installed at the top of the HWRs. A fundamental power coupler is installed at the bottom of the HWR. The design parameters of the KOMAC cryomodule are summarized in Table 2. The length and diameter of the helium vessel is 3,600 mm and 1,200 mm respectively. The total length of the cryomodule including supply end can and return end can is 5,430 mm. The dynamic heat load assumes10% RF duty. The total dynamic heat load comes from 1 nohm BCS resistance at 2 K, 3 nohm due to 15 mG magnetic field and 16 nohm due to residual resistance. The heat load comes from U-tube is referenced to SNS cryomodule results [3]. Total heat load per cryomodule is 24.2 W at 2 K and 149 W at 50 K which corresponds to 85 W at 4 K equivalent heat load. The designed cross sectional view of the cryomodule is shown in Fig. 3. The cryomodule including two end cans is shown in Fig. 4. The empty space in KOMAC linac tunnel is 40 m which is available for the matching section and HWR. In order to increase proton energy from 100 MeV to 180 MeV, we need 28 HWR cavities and 7 cryomodules. The peak RF power for one HWR cavity is 120 W including 100 % margin in order to cover the Lorentz force detuning and tuner capability.

Table 2: Design Parameters of the Cryomodule

Parameter	Unit	Value
Cavity temperature	K	2
No. of cavities / cryomodule	-	4
Cryomodule length (including end cans)	mm	3,600 5,430
Cryomodule diameter	mm	1,200
Radiation heat shield temperature	K	50
Magnetic field reduction	mG	15
Heat load (2K/50K)		
Static	W	10.4 / 125
Dynamic	W	3.8 / -
U-tube and line	W	10 / 24
Total heat load per cryomodule	W	24.2 / 149

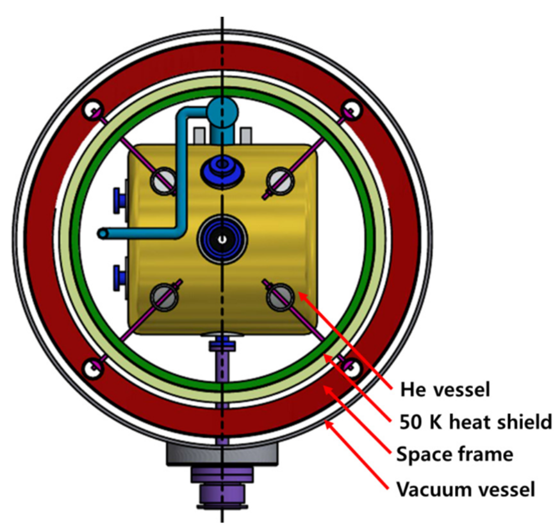

Figure 3: Cross sectional view of the cryomodule.

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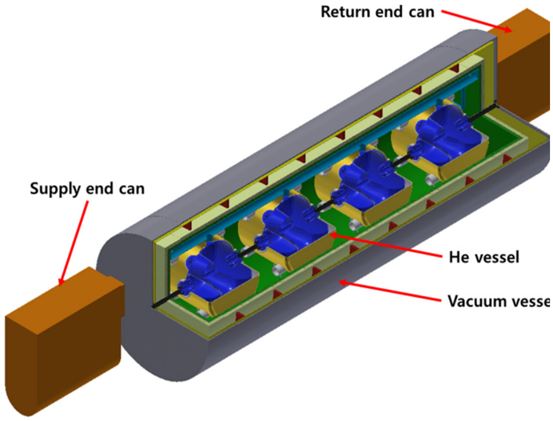

Figure 4: KOMAC HWR cryomodule.

SUMMARY

A HWR is considered as a possible candidate to accelerate 100 MeV proton beam to 160 MeV without modification of the existing KOMAC linac tunnel in order to expand the application field of the KOMAC linac into the pulsed neutron source. A preliminary design of the cryomodule was carried out. A cylindrical shape cryomodule was considered with a motivation of the nearly symmetric dimension of the HWR. Overall geometry and heat load were decided based on the experience and data of the other operating facilities. Prototypings of the HWR and test cryomodule are planned in near future.

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