ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-WEPM013

HPRF SSPA SYSTEM FOR RAON SRF CAVITIES

Kyungtae SEOL†, Kitaek SON, Doyoon LEE, Ohryong CHOI, Hyunik KIM
Rare Isotope Science Project, Institute for Basic Science, Daejeon, Korea

Abstract

The heavy-ion accelerator of the Rare Isotope Science Project (RISP) in Korea has been developed. There are three types of SRF cavity, which are 81.25 MHz quarter-wave resonator (QWR), 162.5 MHz half-wave resonator (HWR), 325 MHz single-spoke resonator (SSR). There are 22 QWRs and 102 HWRs in the superconducting linac#3 (SCL3), and 69 SSR1s and 144 SSR2s in the superconducting linac#2 (SCL2). The required RF power is 4 kW for each QWR, 4 kW for each HWR, 8 W for each SSR1, and 20kW for each SSR2. The high power RF SSPAs for the SRF cavities have been developed and fabricated with domestic companies. 325 MHz 20 kW SSPAs have been designed and fabricated to test the prototype of the SSR2 SRF cryomodule including six SSR2 cavities. They were designed to enable full-reflection operation at all times. It consists of four 6 kW power units, four 6 kW circulator units, 4-way combiner, a control unit, a power distribution unit, and cooling water inlet/outlet manifolds in each 19" rack. The power-unit has six 1.2 kW pallets and circulators, and three power packs. This paper describes the design and fabrication of the SSPA systems for the RAON SRF cavities.

INTRODUCTION

The RAON accelerator has been developed to study a wide range of cutting-edge science programs in atomic physics, material science, bio and medical science, nuclear astrophysics, nuclear science, and interdisciplinary science programs at the Institute for Basic Science (IBS) [1-2].

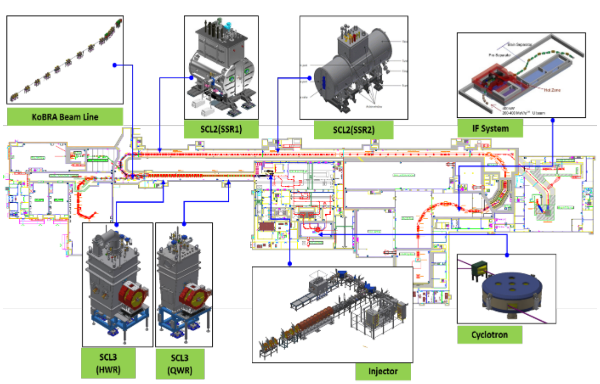

Figure 1: Layout of the RISP accelerator system.

The accelerator facility is shown in Fig. 1. The injector system comprises an electron cyclotron resonance ion source, a low-energy beam transport, a radio-frequency quadrupole (RFQ), and a medium-energy beam transport (MEBT). The superconducting driver linac accelerates the beam to 200 MeV/u. A low-energy superconducting linac (SCL3), a post-accelerator to driver linac (P2DT) and a high-energy superconducting linac (SCL2). The SCL3 accelerates the beam to 18.5 MeV/u. The SCL3 uses two different families of superconducting resonators, i.e., a quarter wave resonator (QWR) and a half wave resonator (HWR). It consists of a total of 22 QWR operating at 81.25 MHz frequency and 102 HWR operating at 162.5 MHz frequency. The SCL2 uses two different types of single spoke resonators (SSR1 and SSR2) and both types will operate at 325 MHz of frequency [3].

HPRF SSPA

The HPRF specifications of SSPAs are summarized in Fig. 2. There are a 150 kW SSPA for RFQ and four SSPAs (4 kW*2, 15 kW, 20 kW) for MEBT in SCL3, which are normal conducting cavities as an injector. The required RF power is 4 kW for QWRs and 4 kW for HWRs in SCL3, and 8 kW for SSR1s and 20 kW for SSR2s in SCL2. Figure 3 shows the SSPAs installed at each SCL gallery. The SSPAs of SCL3 have been operating for beam commissioning of SCL3 [4]. Figure 4 shows the RF power level of the SSPAs on SCL3 beam commissioning.

◆ HPRF : SSPA(Solid-State Power Amplifier

	Cavity	Quantity (EA)	Frequency (MHz)	RF Power (kW)	RF Transmission Line
SCL1 (Pended)	RFQ	2	81.25	80	6 1/8 inch EIA
	Rebuncher	4	81.25	20,15,4	3 1/8 inch EIA
	QWR	22	81.25	4	1 5/8 inch EIA
	HWR	102	162.5	4	1 5/8 inch EIA
SCL2	SSR1	69	325	8	3 1/8 inch EIA
	SSR2	**144**	**325**	**20**	**4 1/16 inch EIA**
SCL3	RFQ (NC)	1	81.25	160 (80*2)	6 1/8 inch EIA
	Rebuncher (NC)	4	81.25	20,15,4*2	3 1/8 inch EIA
	QWR	22	81.25	4	1 5/8 inch EIA
	HWR	102	162.5	4	1 5/8 inch EIA
P2DT & CSS	HWR	4 +2	162.5	4	1 5/8 inch EIA

Figure 2: HPRF SSPA specifications.

Figure 3: SSPAs for SCL3(left) and SSPAs for SSR1(right) installed in each gallery.

† ktseol@ibs.re.kr

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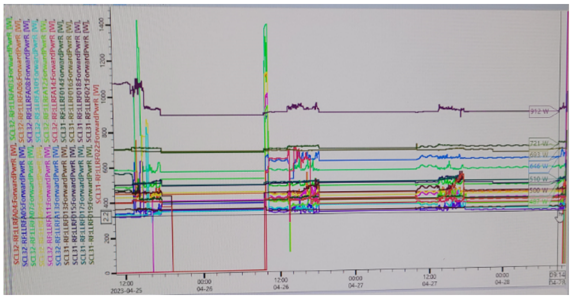

Figure 4: RF power levels of the SSPAs on the SCL3(QWR, HWR) beam commissioning.

SSPAs were designed and fabricated to test a SSR2 cryomodule including six cavities. Power rating of SSPA was calculated by considering beam current, cavity detuning, and optimal loaded-Q. The optimal loaded-Q and RF power requirement for SSR2 were shown in Fig. 5. The detuning of ±80 Hz and optimal loaded-Q of 2.0E+6 was considered, so the power rating of 20 kW was determined for SSR2. In our case, SSPA will be operated in almost full reflection to secure control bandwidth. Figure 6 shows the configuration of a 20 kW rack and the SSPAs was fabricated with a local company. There are four 5 kW power amplifier units, four circulator units, a control unit, and a power distribution unit. Control and operating interface based on EPICS was implemented as shown in Fig. 7.

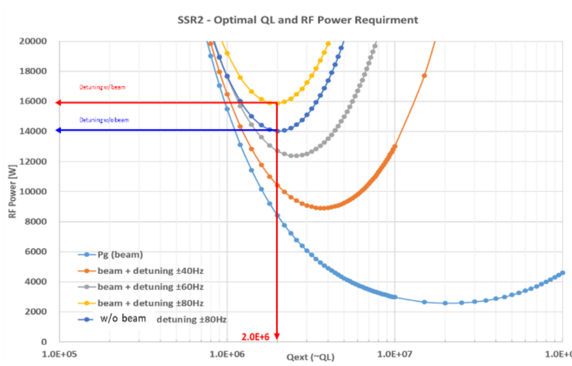

Figure 5: RF power calculation for the SSR2 cavity.

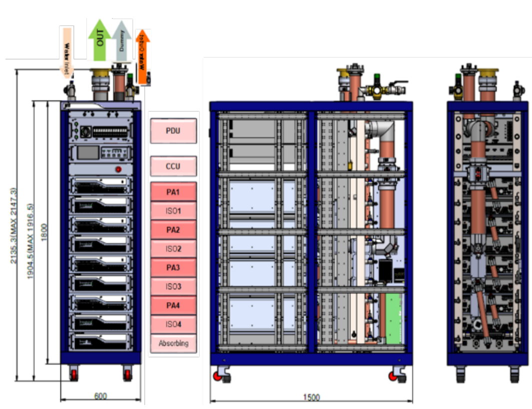

Figure 6: 20 kW SSPA configuration for SSR2.

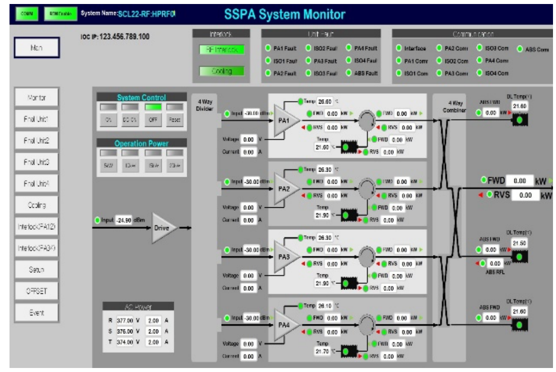

Figure 7: Control and OPI based on EPICS.

Six SSPAs was installed in SRF test facility building as shown in Fig. 8. High power RF test was performed. In the case of the SSR2, SSPA will be operated in almost full reflection to secure control bandwidth, so return loss of circulator according to phase change was checked in full reflection test. The return loss was higher than 15 dB as shown in Fig. 9. The SSPAs was tested in 20 kW full power as shown in Fig. 10. RF power, efficiency, harmonic, spurious, gain, gain linearity, and cooling water were also tested. The SSPAs have been operating for the SRF cryomodule test.

Figure 8: SSPAs installed for the SRF cryomodule test.

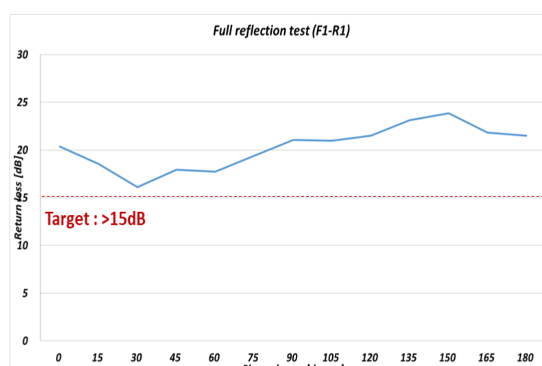

Figure 9: Return loss measurement of circulator according to phase change in the high power test.

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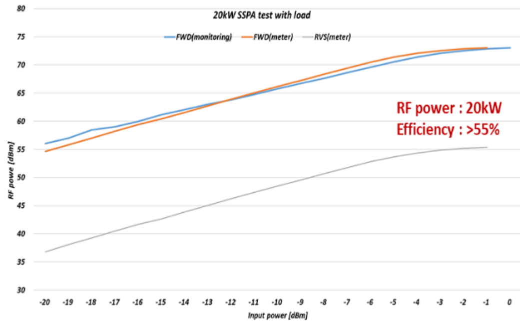

Figure 10: 20kW RF power test of the SSPA.

SUMMARY

The high power RF SSPAs were designed and fabricated for the SRF cavities. The SSPAs for SCL3 (RFQ, MEBT, QWR, HWR) have been operating for the beam commissioning. The SSPAs for a SSR2 cryomodule test was fabricated. The required RF power was calculated by considering beam current, cavity detuning, and optimal loaded-Q. The SSPAs was fabricated considering that it will be operated in almost full reflection. The high power RF test was performed with a termination and a movable short. The SSPAs have been operating for the SRF cryomodule test.

ACKNOWLEDGMENTS

This work was supported by the Rare Isotope Science Project which is funded by the Ministry of Science, ICT and Future Planning (MSIP) and the National Research Foundation (NRF) of the Republic of Korea under Contract 2011- 0032011

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