Operational experience of QWR cryomodules for RAON

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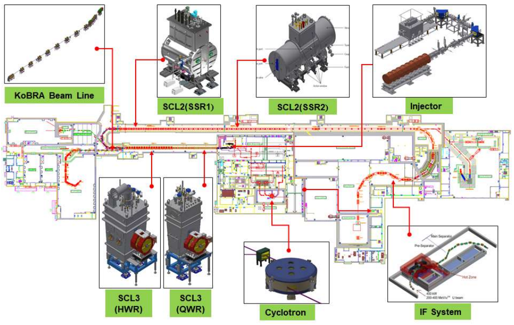
Abstract

Low energy linac(SCL3) of RAON (Rare isotope Accelerator complex for ON-line experiment) has been commissioned since 2023. SCL3 is composed of two types of superconducting cavity, which are QWR (Quarter wave resonator) and HWR (Half wave resonator). The stable operation of cavities was limited due to the imperfect performance of tuners in QWR cryomodules. Also, the various disturbances originated from the cryogenic system, utilities, and so on causes the failures of the superconducting cavities. Since QWRs are operated in 4.5 K, the main disturbances are related with the cryogenic system such as helium pressure, helium flow rate, valve movement and so on. The operational experience which is focused on the causes of cavity failures and source of disturbances of QWR cryomodules of RAON will be introduced.

Overview



	QWR	HWR	SSR1	SSR2
Optimum β	**0.049**	0.13	0.32	0.51
$f\ [MHz]$	**81.25**	162.5	325	325
$V_{acc}\ [MV]$	**1.07**	1.47	2.36	4.1

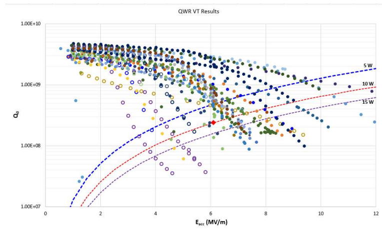
	Cavity	# of cav. per CM	# of CM	Op. T (K)
SCL3	QWR	1	22	4.5
	HWR	2	13+2	2.05
		4	19	2.05
SCL2	SSR1	3	23	2.05
	SSR2	6	23+2	2.05

QWR HWR SSR1 SSR2

The low energy superconducting linac (SCL3) of RAON is composed of 22 quarter wave resonator (QWR) cryomodules and 35 half wave resonator (HWR) cryomodules including two bunching HWR cryomodules in bending section (P2DT).

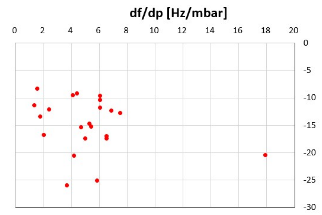
The mass-production of SCL3 cryomodules was started in December, 2017 and finished in November 2021. The low energy linac of RAON was installed in the tunnel on December 2021. SCL3 was cooled down in September 2022 and the first beam commissioning was finished in May 2023. The 2nd operation of SCL3 conducted for experiment with low energy experimental systems such as KOBRA and NDPS in 2024.

Characteristics of QWR cavities and cryomodules



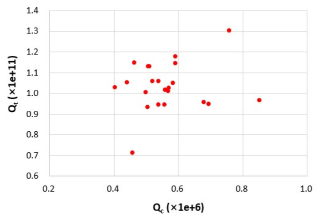
Q_0 vs E_{acc} of QWR

- Requirement: Q_0=2.4e+8@4.5 K, 6.1 MV/m
- Main cause of failure was field emission.



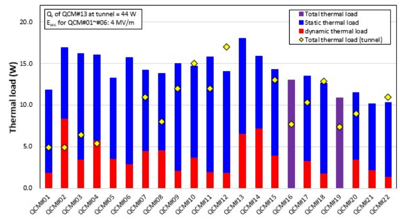
df/dp and LFD of QWR measured in HT

- Average df/dp and LFD are 4.5 Hz/mbar and -14.6 Hz/(MV/m)^2, respectively



External Q's of QWR measured by VNA

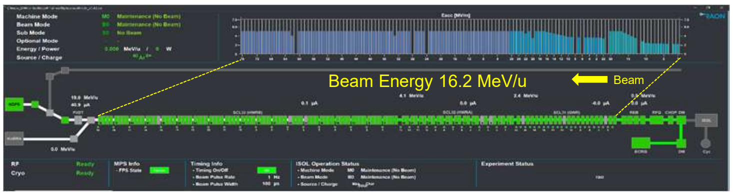
- Q_{ext} of FPC: control bandwidth and RF power
- Averaged control BW: 149 Hz



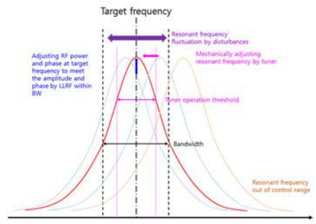
Total thermal load measured in HT and tunnel

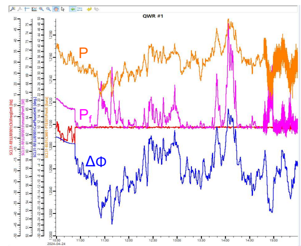
- Requirement in HT: 20 W at 4.5 K and 6.1 MV/m
- Some cavities degraded after installation.

Operation of QWR cryomodules

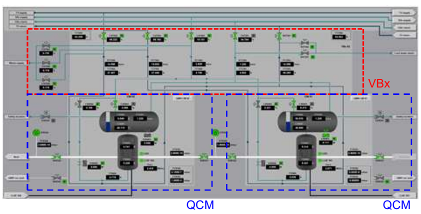


- 8 cavities (out of 124) were not used due to lack of spare SSPA (Q3, Q12, Q21), control issue(HA6, HA8, HB24, HB28, HB61).
- Accelerating fields: QWR < 5 MV/m, HWR < 5 MV/m
- Beam commissioning with $^{40}Ar^{8+}$ and experiment with KoBRA and NDPS for external users.
- RI beam ($^{25}Na^{5+}$) from ISOL was successfully accelerated by SCL3.

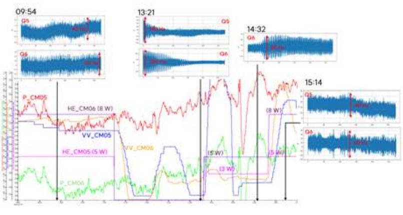




- RF control of superconducting cavity
  - Essential for stable operation of accelerator
  - Maintaining amplitude and phase of electric field in the cavity
  - Requirement for RAON cavity: ±1% (peak-to-peak) amplitude, ±1°(peak-to-peak) phase

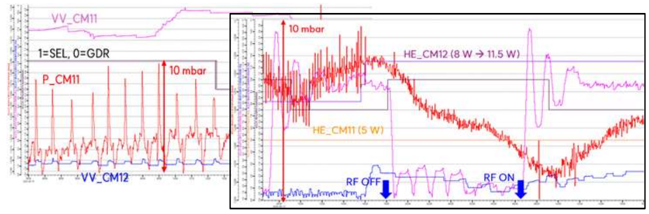


- Two QCMs are connected with one valve box.
- Merge of He flow in the valve box caused pressure instability and vibration when the evaporated flow rate from each QCM was unbalanced.
- The instability was overcome by adjusting the heater power on the reservoirs.



Instability of QCM05 and QCM06

- Frequency fluctuation of cavities measured by LLRF system in SEL mode.
- When the heaters were turned off, frequency fluctuation of both cavities increased up to 150 Hz and 300 Hz and slow pulsation was observed.



Instability of QCM11

- Q12 was not operated and 8 W heater power supplied to compensate the dynamic heat load of the cavity.
- Failure of control was experienced due to the pressure fluctuation up to 10 mbar in QCM11.
- The pressure fluctuation of QCM11 was caused by the movement of JT valve in QCM12.

Summary

The main source of disturbance for QWR is pressure variation since QWRs are operated in 4.5 K and 1.25 bar. Despite the wide control bandwidth of QWR, instability occurred due to the unbalanced flow rate from QCMs connected in one valve box. The instability was successfully overcome by adjusting the heating power of heaters installed on the reservoirs.

기초과학연구원 Institute for Basic Science

RAON Rare isotope Accelerator complex for ON-line experiments

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