CRYOMODULE AND POWER COUPLER FOR RIKEN SUPERCONDUCTING QWR

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Abstract

We report a general description of the cryomodule for the RIKEN superconducting quarter-wavelength resonator, the construction of which is now in progress and is aimed to be completed within this fiscal year.

OVERVIEW

At the RIKEN Nishina Center, the construction of an accelerator system based on the superconducting quarter-wavelength resonator (QWR) is underway with the goal of developing basic technologies for the low-beta superconducting linear accelerator for ions [1]. A cryomodule that can mount two QWRs is now being constructed as a prototype. The fabrication of one QWR has been completed and a performance test has been carried out. The result of the performance test is reported in Ref.2 [2].

The overall structure and the design parameters of the cryomodule are shown in Fig. 1 and Table 1. Detailed design parameters of the QWR are described in Ref. 2. The vacuum vessel has a cylindrical shape. The vacuum of the QWR is separated from that of the whole system. As the first step, one actual QWR and one dummy cavity will be mounted in the cryomodule. The general descriptions of the components of the cryomodule other than the QWR are given in the following section.

Table 1: Design Parameters of the Cryomodule

Resonant freq. of QWR	75.5 MHz
Inner diameter of QWR	300 mm
Cavity height of QWR	1055 mm
Gap length of QWR	60 mm
Beam aperture	40 mmϕ
Operating temperature	4.5 K
Estimated heat flow	5.0 / 15.0 W/resonator (Cavity / Thermal shield)
Assumed Max. RF power	10 kW

COMPONENTS OF CRYOMODULE

Helium Jacket

The QWR is enfolded in the helium jacket. The helium jacket is made of titanium, which has a coefficient of thermal expansion similar to that of niobium, which is the material of the QWR. The space between the QWR and the helium jacket is filled with the liquid helium to cool down the QWR.

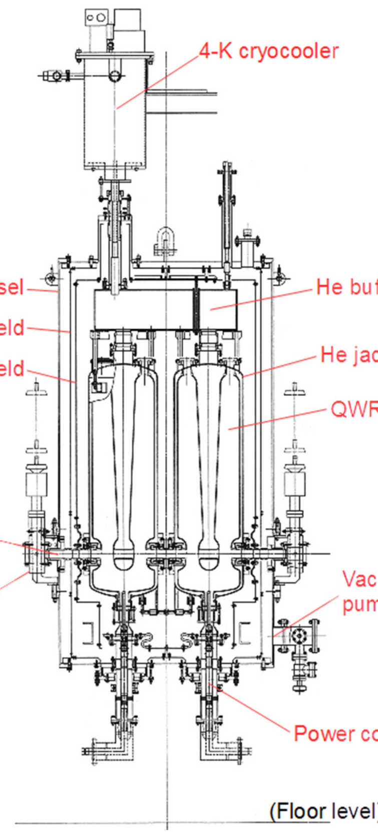

Figure 1: Overall structure of the cryomodule.

4-K Cryocooler

The liquid helium is stored in the helium jacket and the helium buffer tank, and the evaporated helium is re-condensed using 4-K GM-JT cryocoolers. The GM-JT cryocooler adopted here is a V316SLCR, manufactured by Sumitomo Heavy Industries, Ltd. (SHI). This GM-JT cryocooler has a cooling power of 4.2 W/5.0 W at 4.3 K (50 Hz/60 Hz). Three GM-JT cryocoolers will be installed to obtain a cooling power of 12 W at 4.5 K (See Table 1).

Thermal Shield

In order to reduce the heat flow into the QWR, the thermal shield is installed in the cryomodule. In the design stage, two types of the thermal shield were compared: the twofold thermal shields (20 and 80 K) cooled down by the double-stage cryocooler and the onefold thermal shield (40 K) cooled down by the single-stage

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cryocooler. After comparison, the 40-K onefold thermal shield was adopted [3]. The thermal shield, which is made of aluminium with a thickness of 2 mm, is cooled down using a 77-K GM cryocooler CH-110LT, manufactured by SHI. This GM cryocooler has a cooling power of ~100 W at 40 K (50 Hz). It is expected that the thermal shield is practically cooled down to 30–40 K because the cooling power at 40 K is sufficiently large compared to the estimated heat flow into the thermal shield (See Table 1). The thermal shield is enfolded by the superinsulation to reduce the heat radiating from the outer wall.

Magnetic Shield

In order to reduce the geomagnetism, which invades the cryomodule and degrades the performance of the QWR, the magnetic shield, which is made of permalloy with a thickness of 2 mm, is installed in the room-temperature area. The target value of the reduced geomagnetism at the top part of the QWR is 20 mG.

Frequency Tuner

The resonant frequency of the QWR is tuned by distorting the QWR in the beam axial direction to adjust its gap length. In order to achieve distortion of the QWR, the mechanical structure shown in Fig. 2 is installed [4]. The beam port flanges are pressed directly using the presser plate, by pulling the steel wires. There are two devices to pull the steel wires: the combination of the motor and the gear (upper), and the piezo actuator (lower). It is expected that a maximum load of 5000 N applied to each beam port reduces the gap length by 0.38 mm, reducing the resonant frequency by 9.4 kHz. The driving test will be conducted from now.

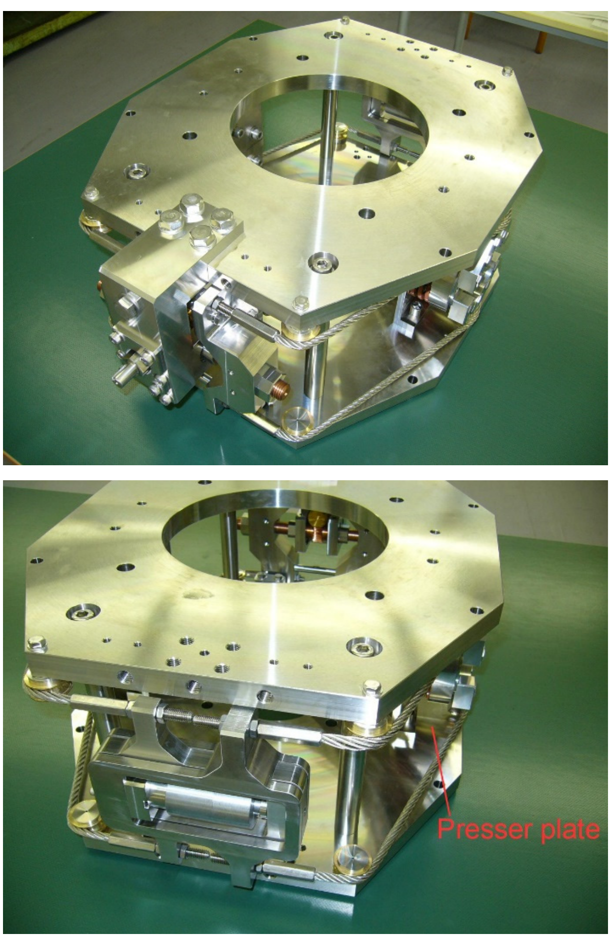

Figure 2: Frequency tuner. Motor-side (upper) and piezo-side (lower).

Power Coupler

The schematic view of the power coupler is shown in Fig. 3. The power coupler has disk-type double vacuum windows. The temperature of the cold window is 40 K. The antenna of the power coupler is made of bulk copper. The inner conductor, upstream of the cold window, and the outer conductor are made of copper-plated stainless steel. The thickness of the copper plating and the position of the cold window were determined in order to optimize the heat flows into both the cavity and the thermal shield [5-7]. The assumed maximum RF power is 10 kW. This power coupler is mounted onto the cryomodule so as to have a variable coupling mechanism that can be tuned without warming up the cold mass or breaking the vacuum of the cryostat.

The fabrication of two power couplers has been completed (see Fig. 4). For these power couplers, the ceramics from two different vendors are adopted for the cold windows: Kyocera 479B and NTK HA997. The ceramic used for the warm windows is Kyocera 479B for both power couplers. The RF processing will be started soon.

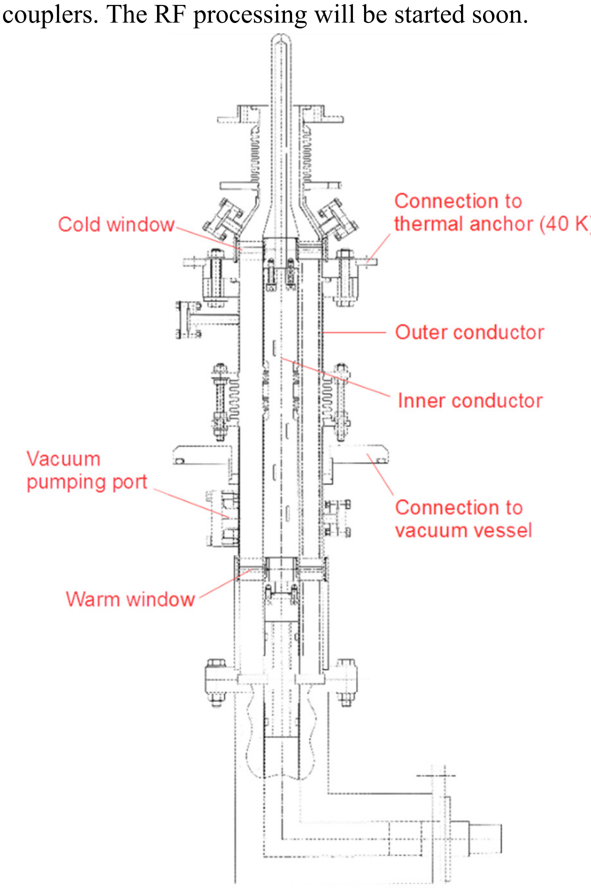

Figure 3: Schematic view of power coupler.

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Figure 4: Completed parts of power coupler (one set).

SUMMARY

At the RIKEN Nishina Center, the construction of the prototype of the acceleration system based on the superconducting QWR is in progress steadily. After an additional performance test, the QWR and other components described in this contribution will be assembled into one cryomodule, and the cooling test will be conducted within this fiscal year.

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REFERENCES

[1] N. Sakamoto *et al.*, "Design studies for quarter-wave resonators and cryomodules for the RIKEN SC-LINAC", in *Proc. 17th Int. Conf. on RF Superconductivity (SRF'15)*, Whistler, BC, Canada, Sep. 2015, paper WEBA06, pp. 976-981.

[2] K. Yamada *et al.*, "First vertical test of superconducting QWR prototype at RIKEN", presented at the 28th Linear Accelerator Conf. (LINAC16), East Lansing, MI, USA, Sep. 2016, paper THPLR040, this conference.

[3] K. Ozeki *et al.*, "Heat flow estimation of the cryomodule for superconducting quarter-wavelength resonator", in *Proc. 12th Annual Meeting of Particle Accelerator Society of Japan*, Tsuruga, Japan, Aug. 2015, paper THP059, pp. 1116-1120.

[4] Mitsubishi Heavy Industries Mechatronics Systems, Ltd., "Superconducting accelerator", PCT/JP2016/54710, Feb. 18, 2016, JP Patent P5985011, 2016.

[5] K. Ozeki *et al.*, "Design of input coupler for RIKEN superconducting quarter-wavelength resonator", in *Proc. 17th Int. Conf. on RF Superconductivity (SRF'15)*, Whistler, BC, Canada, Sep. 2015, paper THPB084, pp. 1335-1339.

[6] K. Kanaoka *et al.*, "Development for mass production of superconducting cavity by MHI", in *Proc. 56th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs (ERL'15)*, Stony Brook, NY, USA, Jun. 2015, paper WEICLH2062, pp. 72-74.

[7] K. Ozeki *et al.*, "Design of input coupler for RIKEN superconducting quarter-wavelength resonator", *RIKEN Accelerator Progress Report Vol. 49,* to be published.