THE EARLY RESULTS OF THE VERTICAL TEST FOR $\beta = 0.12$ HWR AT RISP

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Abstract

The facility for the vertical test at 2 K with the master frequency 81.25 MHz is being prepared at Rare Isotope Science Project (RISP) and the preliminary tests are being done as the preparation progresses. We briefly describe the vertical test system, the tests being done, and the future plan for the completion of the facility.

INTRODUCTION

At RISP [1], 4 different kinds of the superconducting cavities have been developed. Now the fabrication of the cavities is complete and their vertical test is being prepared. At the moment, as a beginning stage, the minimum facility is prepared with the prospect for further expansion and upgrade of the facility. For now, 4 K cryogenic system is prepared and no surface processing facility is available yet. The simple system check and the leak check at cryogenic temperature is examined and some RF measurement including critical coupling calibration and decay time measurement is made.

The future plan includes the construction for surface processing, the implementation of the magnetic shields, 2 K pumping station, LLRF system for the vertical test, adjustable coupler, radiation shields, and the interlock system.

SYSTEM PREPARATION

The vertical test stand consists of the cryostat, the pit, the test insert, the staging rack, and vacuum pump system.

The cryostat (See Fig. 1(a)) is made of the stainless steel STS304: The vacuum vessel is 3300 mm deep with 800 mm inner diameter. The helium vessel is 3000 mm deep 500 mm with inner diameter with about 250 L helium capacity. The helium vessel is surrounded by the thermal shield. The test insert was designed and fabricated. It consists of the top plate, the support cage, and the thermal baffle to reduce the static heat load through the conduction. The top plate is equipped with the pressure relief system, i.e., 8 cm diameter burst disk combined with a re-closable safety relief valve at a set pressure of 1 bar. The relief system is sized assuming complete helium vaporization due to a leak in insulating vacuum. It must also provide the various feedthroughs for the vacuum port (for the cavity), the temperature sensors, level sensors, N and SMA-type RF cables for the input and pick up couplers, LHe input port, and Gas output port. The vacuum pump system for the cavity evacuation was prepared. The system consists of the turbo molecular pump, the scroll pump, the controller, the compressor, the vacuum gauges (low range and the full range), and the residual gas analyzer (RGA) as shown in Fig. 1(c).

(a) Cryostat in the pit

(b) Test insert in the staging rack

(c) Vacuum pump system

Figure 1: Vertical test stand.

A simple cryogenic system to cool down the system to 77 K and 4 K using LN_2 and LHe, respectively, was prepared: The LHe dewar, GHe tank, LN_2 dewar, the thermometry sensors, the pressure transducer, and the level sensors. 2 K pump station will be added in near future.

The RF system is being installed to test the HWR with the resonant frequency of $f = 81.25$ MHz. The vertical test is generally done in critical coupling [2]. In the critical coupling, the bandwidths are very narrow and low power corresponding to the wall loss will be supplied.

The schematic of the RF system is given in Fig. 2. As shown in Fig. 2, the system consist of the signal generator, RF switch, the vertical test LLRF, the driving amplifier, the circulator, the directional coupler, the adjustable coupler, the power meters, and the oscilloscope with the diodes.

PRELIMINARY MEASUREMENTS

During the first cool down, the preliminary RF measurements were done using the vector network analyzer (VNA) only. Using the VNA, the frequency shift during the evacuation, the cool down (to 4 K), and the helium pressure pres-
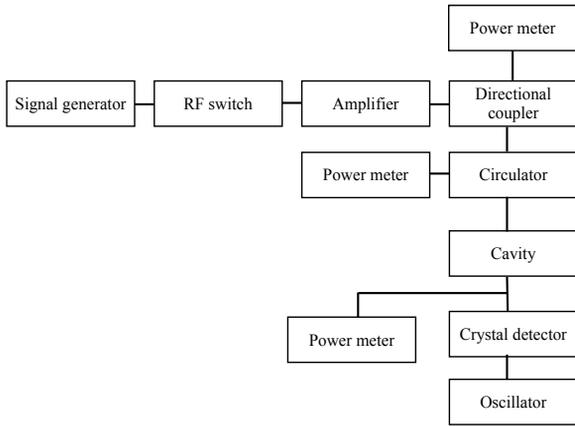
Figure 2: Schematic of the RF system.

surization were measured. (The last were used to estimate the helium pressure fluctuation sensitivity) The decay time and the Q_e were measured during the second cool down.

As a commissioning of the vertical test system, we performed a few preliminary measurements of the cavities. To commission the various vertical test subsystems including the cryogenic system, the RF cables, the pump system, and the sensors, and do leak test at the cryogenic temperature, we cool down the cavity to 77 K using LN_2 and subsequently 4 K using LHe. As shown in Fig. 3, the pressurization by 1.5 psi made cool down fast enough so that the parking zone (between 60 and 150 K) was passed within 45 minutes [3], which is much shorter than tolerance limit, 1 hour. In addition, we also measure the resonant frequency using the vector network analyzer (VNA). The measured frequency changed from 162.881 MHz at 301 K to 163.124 MHz at 4.2 K. The change in frequency is

$$\Delta f = 243 \text{ kHz}. \tag{1}$$

This is roughly the same as the expected value from the analytic calculation: From $\delta f / f = -\delta l / l = 0.155$, we have $\delta f = 252$ kHz.

In general, the various quality factors are related as follows.

$$\frac{1}{Q_L} = \frac{1}{Q_0} + \frac{1}{Q_e} + \frac{1}{Q_t} \tag{2}$$

In the 2-port system, the critical coupling is realized if

$$\frac{1}{Q_0} + \frac{1}{Q_t} = \frac{1}{Q_e}, \tag{3}$$

which implies $Q_e = 2Q_L$. [4] Then in $Q_t \gg Q_0, Q_e$ limit, Q_0 is computed to be

$$Q_0 \approx 2Q_L + \frac{4Q_L^2}{Q_t}, \tag{4}$$
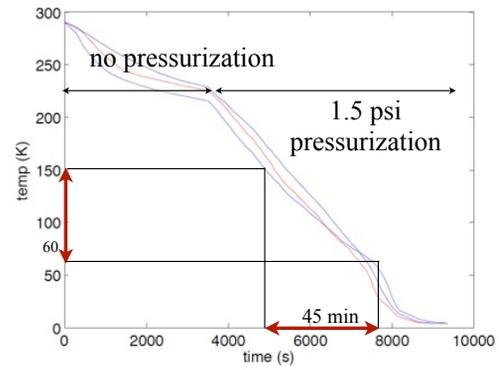
(a) Temp. vs time plot
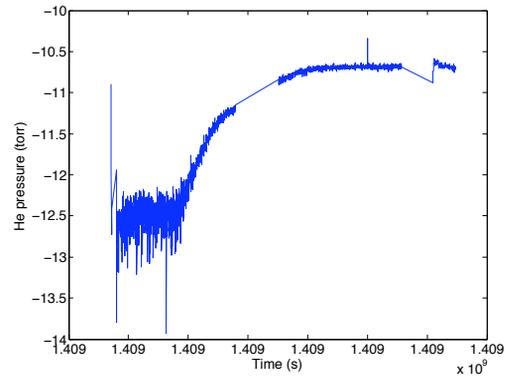
(b) Helium gas in the cavity
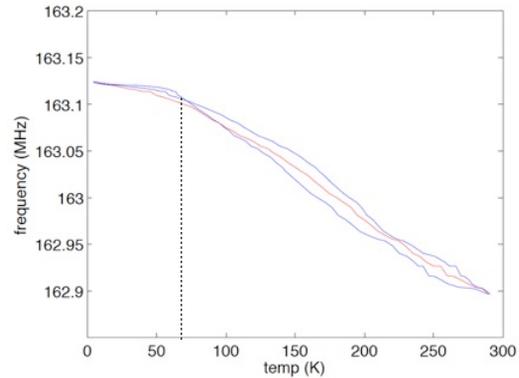
(c) Freq. vs temp. plot

A different color corresponds to a different temp. sensors.

Figure 3: Cool down data.

which makes it possible to obtain Q_0 from Q_L, i.e., $Q_0 \approx 2Q_L$. The Q_L is obtained by the measurement of the decay time τ via the relation

$$Q_L = \pi f \tau, \tag{5}$$

where f is the resonant frequency of the cavity. Therefore, the measurement of the decay time at critical coupling would give us the Q_0 in a good approximation.

The measurements of the decay times at the critical coupling are done in three steps: with the copper cavity at room temperature, with niobium cavity at 77 K (including the room temperature measurement), and with the niobium cavity at 4 K. To achieve the critical coupling with the fixed coupler in general, we first manufacture the antennae whose lengths are determined according to (3), once the Q_0 and Q_t are known.
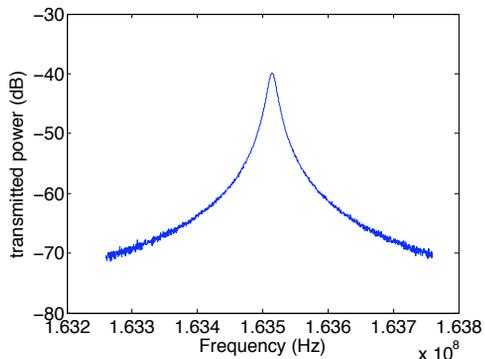
Figure 4: The measured S_{12} of the copper cavity at room temperature.

The decay time τ_c of the copper cavity is measured to be $\tau_c = 21.5\ \mu$s, which translates to $Q_L = 1.1 \times 10^4$, which agrees with the measurement by the VNA.
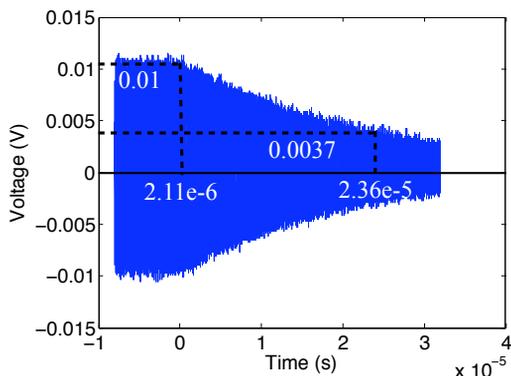
Figure 5: Decay time measurement of the copper cavity at room temperature.

Secondly, we measured the decay time of the niobium cavity in the critical coupling at 77 K. We first estimate the Q_0 of the niobium cavity at 77 K by CST-MWS simulation. The expected Q_0 was $Q_0 = 2 \times 10^4$. Using Q_t from room temperature and (3), we expect Q_e to be $Q_e = 1 \times 10^4$ at 77 K. At room temperature where the fixed coupler antenna can be easily exchanged, we fixed the antenna length by repeated measurement of the Q_L and subsequently Q_e. After cool down to 77 K, we measured the decay time τ and critical coupling by the VNA. The measured decay time was
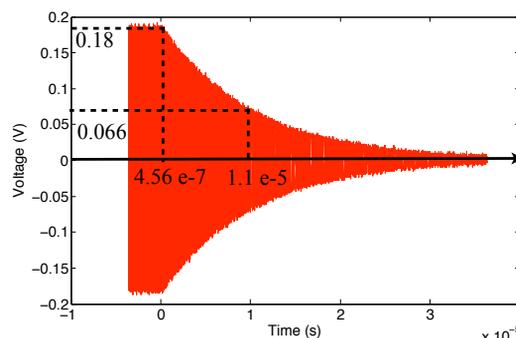
Figure 6: The decay time of the Nb cavity at 77 K.

$\tau = 10.04\ \mu$s, which leads by (5) to $Q_L = 5.13 \times 10^3$. This is compared with the measurements by the VNA in Table 1.

Table 1: The Measurement by VNA at 77 K

Quantity	Unit	Value
Q_L	-	4816
VSWR_e	-	1.054
VSWR_t	-	60.7
β_e	-	0.949
β_t	-	0.017
Q_0	MHz	9465

Finally, we plan to measure the decay time of the niobium cavity in the critical coupling at 4 K in near future.

ACKNOWLEDGMENT

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