STATUS OF DEVELOPMENT OF THE CERL SUPERCONDUCTING INJECTOR LINAC

K. Watanabe#, E. Kako, S. Noguchi, M. Sato, T. Shishido, Y. Yamamoto, KEK, Tsukuba, Ibaraki 305-0801, Japan

Abstract

Development of the superconducting injector linac for the compact ERL has been continuing at KEK. The cryomodule including three two-cell SC cavities was designed. Two prototype two-cell cavities were fabricated, and the vertical tests within without HOM pick-up probe were carried out after the standard surface preparation at KEK-STF. The status of the component for the cERL injector linac will be reported.

INTRODUCTION

An injector for cERL is required to accelerate a CW beam of 100 mA to 10 MeV [1]. In this application, critical hardware components are not cavities but RF input couplers and HOM dampers.

TWO-CELL CAVITY

The prototype 2-cell #2 cavity is shown in Figure 1. This cavity was fabricated at 2009. It has a TESLA-like cell shape and larger beam pipe aperture of 88 mm. This cavity was equipped five loop type coaxial HOM couplers on both beam pipes to obtain strong damping for 2nd monopole mode [2].

Three vertical tests within without the HOM pick-up probe were carried out from Feb 2010 to Aug 2010. In the 1st vertical test, the HOM pick-up probes did not equip to the HOM couplers for performance testing of the method of the fabrication and the surface preparation. The gradient was reached 40.9 MV/m in TM_{010} pi-mode. It is very successful result. In the 2nd test, the HOM pick-up probes equipped to all HOM couplers for performance testing of the rf design of the HOM coupler. The equipped the HOM feed though (Al_2O_3 window) is made by Kyocera. The material of HOM pick-up probes is the niobium. However, unfortunately vacuum leak was happened during first power rise at 2K. The test was stopped at 14 MV/m, but thermal instability was not observed [2].

The vertical test with the HOM pick-up probe was made again in end of August 2010. The result of this test will be reported in the following section.

Tuning of the HOM couplers

The tuning of the HOM couplers for TM_{010} pi-mode made after hanging to the vertical test stand. The frequency of TM_{010} pi-mode at room temperature was 1296.735 MHz. The HOM couplers were tuned to become the smallest output power from the HOM pick-up at room temperature. These output signals are small about -10 dB in comparison with the monitor port (Qt). Measured Qext of the HOM couplers for TM_{010} passband at low temperature is summarized in Table 1. Measured Qext of all HOM couplers were weak in comparison with the required value (2 x 10^11). Measured Qext of HOM couplers for TM_{010} pi/2-mode were 2.3 ~ 6.6 x 10^9 due to the bandwidth performance of the notch filter.

Figure 2 shows the frequency dependence of the Qext of the HOM couplers and the frequency change of TM_{010} pi-mode during cool down from 4.2 K to 1.7 K.

Figure 1: 2-cell cavity #2 (five HOM couplers)

Table 1: Qext of the HOM couplers for TM_{010} passband

Coupler	**TM_{010} Pi-mode** Fo=1298.54 MHz 1.73 K	**TM_{010} Pi/2-mode** Fo=1285.32 MHz 1.17 K
HOM1	6.80 x 10^11	6.60 x 10^9
HOM2	3.92 x 10^12	4.79 x 10^9
HOM3	3.45 x 10^11	6.12 x 10^9
HOM4	2.45 x 10^12	4.98 x 10^9
HOM5	6.11 x 10^11	5.64 x 10^9
Monitor	2.26 x 10^11	2.32 x 10^9

High field processing

In the first power rise, a quench happened on the HOM1 pick-up at 18 MV/m after keeping 40 second. The sustainable gradient and time rose during the high field processing. The result of the high field processing at TM_{010} mode shows in Figure 3. Finally, the maximum instantaneous gradient was achieved 38.4 MV/m. The field was kept 0.1 second at the maximum gradient then a quench happen on the one HOM pick-up probe (HOM1). The sustainable gradient at CW was 19 MV/m at 1.5 K when the helium level was higher than the top flange of the cavity.

After the high field processing, TM_{010} pi/2-mode excited to estimate the feed through performance for the transmission power from the HOM couplers. Figure 4 shows the correlation of the Qext and the output power from the HOM couplers. The Qext value changed to strong coupling side due to thermal expansion of the HOM pick-up probe by heating, when the output power was over 5 W around 10 MV/m, then the Qo value also decreased smaller than 10^9 due to the HOM pick-up probes were transition to the normal conduction.

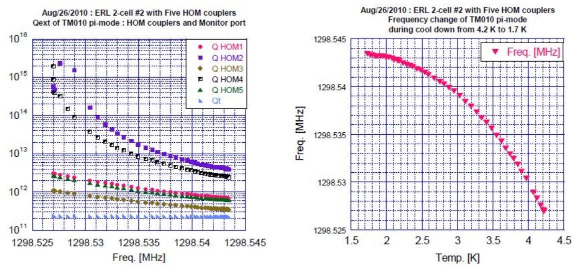

Figure 2: Frequency dependence of Qext of the HOM couplers measured during cool down

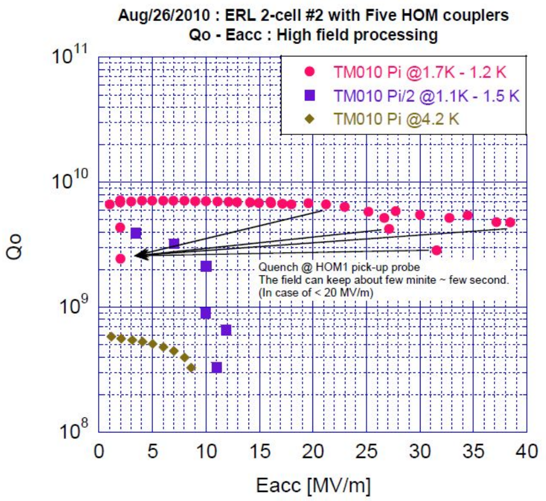

Figure 3: $Q_0 – E_{acc}$ curve

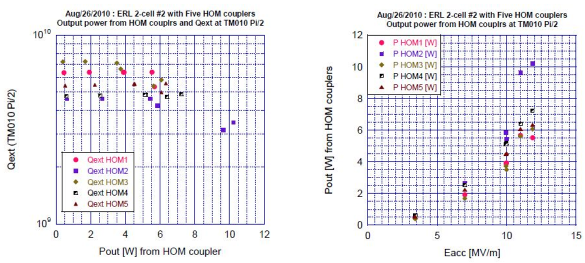

Figure 4: Output power from the HOM couplers and Qext value for TM_{010} pi/2

Correlation of the cooling condition and the sustainable gradient

The sustainable gradient changed by the cooling condition around the cavity. To estimate the rf design of the HOM coupler, the relations between the helium level, helium temperature and the sustainable gradient measured during this test after high field processing for the cryomodeule operation.

Figure 5 shows the location of the attached thermo-sensors and the helium level around top of the cavity. The tested items are shown as followings,

(1) The helium level was higher than the top flange of the cavity then the helium temperature was lower than 2 K. The gradient was risen to 1MV/m step after keeping 10 min from 16 MV/m to the quench field.

(2) The helium temperature kept to 2 K controlled by a heater and the cooling performance, then the gradient was risen to about 0.3 MV/m step after keeping 30 min from 16.2 MV/m to the quench field.

(3) The gradient kept 16 MV/m at 2K then the helium level measured that the gradient is kept 16 MV/m.

(4) Equipped two HOM couplers (HOM1 and HOM2) on top of the cavity do not dip on the liquid helium then the sustainable gradient measured. The rf cable from HOM1 and HOM2 also do not dip on the liquid helium. The pressure of inside cryostat was 3 kPa.

The result of these items is summarized in Table 2. The output signal from quenched HOM coupler increased although the gradient dropped in the cavity quenched by the HOM1 pick-up probe (Table 3). The history of temperature response of HOM1 and HOM2 in item (2) and (4) is shown in Figure 6 and 7. The HOM3, HOM4, HOM5 and the cells were not happen a thermal instability during this test.

Table 2: Correlation of the cooling condition and the sustainable gradient

Item	The sustainable gradient and the quench field.	Cooling condition He temperature He level: 1cm /1%
(1)	16 ~ 19 MV/m (kept) 20 MV/m (Quench) HOM1 pick-up after keeping 60 second.	1.4 ~ 1.53 K He level: ~95.3%
(2)	16.2 ~ 17.4 MV/m (kept) 17.9 MV/m (Quench) HOM1 pick-up after keeping 70 second)	2 K He level: 95.3 ~ 70%
(3)	16 MV/m (Quench) HOM2 pick-up when the helium level was 50.1 %. 13 MV/m (Quench) HOM1 after keeping 80 second when the helium level was 44 %.	2 K He level: 68 ~ 44 %
(4)	12 MV/m (No quench at all HOM pick-up probe)	2 K He level: 50.3 ~ 46.9 %

Re-estimate probe surface current to achieve target gradient

In case of the HOM couplers do not dip on the liquid helium, measured sustainable gradient was 12 MV/m. The reason of the limitation was a quench on the HOM1 pick-up probe due to the induction current by magnetic field around HOM pick-up probe. The gap between the inner conductor and the HOM pick-up probe estimated using by result of this test to achieve the target gradient in cryomodule operation. The calculation result shows Figure 8. The sustainable gradient is assumed 16 MV/m in the vertical test to changes the gap from 0.5 to 2.0 mm. Of cause, the damping performance of HOMs also needs to measure in case of 2 mm gap.

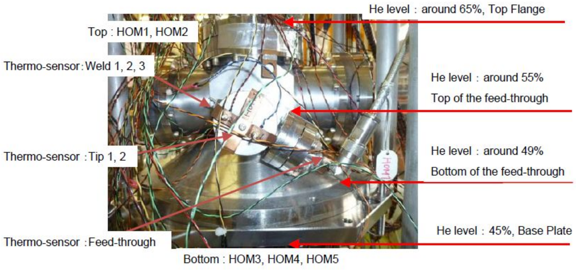

Figure 5: Location of the thermo-sensors and the helium level

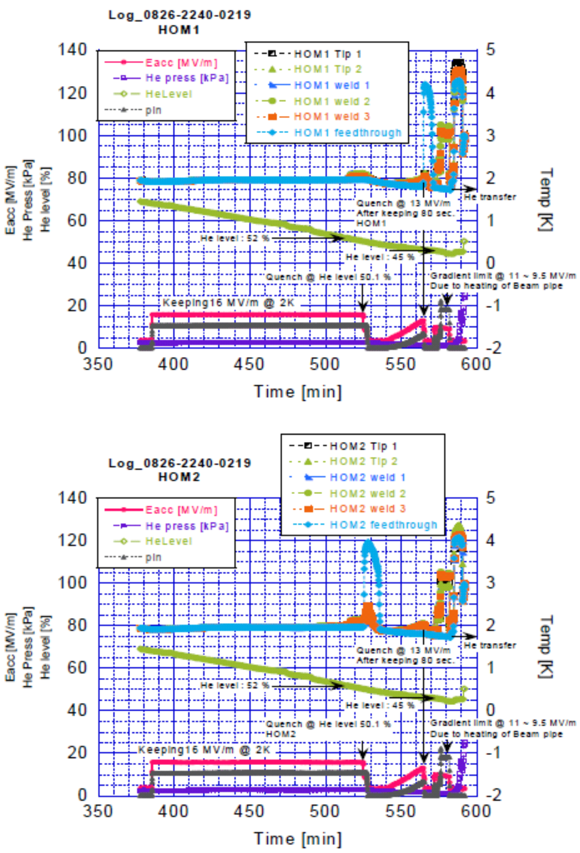

Figure 6: During the item (2)

SUMMARY AND PLAN

Third vertical test with HOM pick-up probe was carried out at Aug 2010. The maximum instantaneous gradient was achieved 38.4 MV/m, then a quench happen on one HOM pick-up probe. Measured sustainable gradient was 12 MV/m when the HOM couplers and rf cables equipped on top side of the cavity do not dip on the liquid helium at 2 K.

Fourth vertical test of the prototype 2-cell #2 cavity with HOM pick-up probe will be made at Oct 2010 to change to 2 mm gap between the inner conductor and the pick-up probe of HOM couplers.

Table 3: Ratio of output signal from the HOM couplers before and after quench of HOM1 pick-up during (2).

Coupler	16 MV/m Before	7.5 MV/m After	Ratio
HOM1	21.9 μW	7.5 μW	0.342
HOM2	3.29 μW	0.71 μW	0.216
HOM3	6.01 μW	1.29 μW	0.215
HOM4	0.643 μW	0.136 μW	0.212
HOM5	129 μW	26.7 μW	0.207

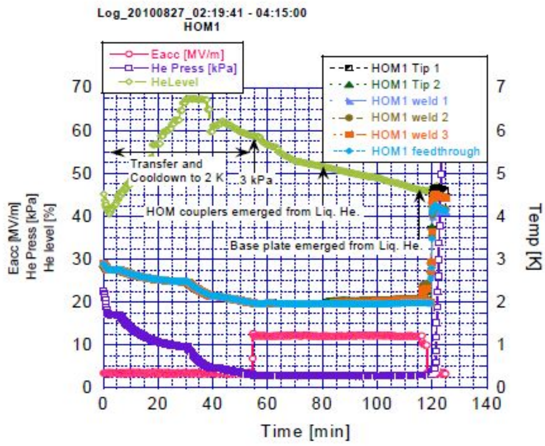

Figure 7: During the item (4)

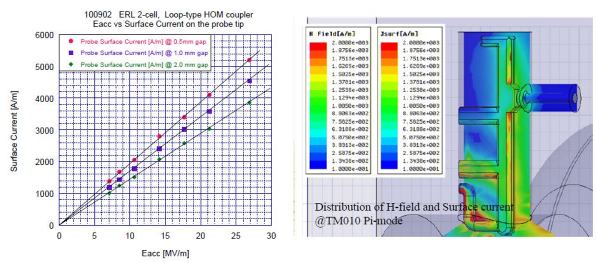

Figure 8: Distribution of H-field and the surface current on the probe tip at each gradient excited by TM_{010}

REFERENCES

[1] S. Sakanaka, et al.,Proceedings of IPAC10, Kyoto, Japan, April 2010, TUPF091.

[2] S. Noguchi, et al., Proceedings of IPAC10, Kyoto, Japan, April 2010, WEPEC024.