PRESENT STATUS OF SUPERCONDUCTING CAVITY SYSTEM FOR CERL INJECTOR LINAC AT KEK

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Abstract

Construction of the compact ERL (cERL) [1] is underway and fabrication of a SC Cavity Injector Cryomodule has been started last year at KEK. Status of R&D and design details are reported.

INTRODUCTION

An injector for the proposed KEK-ERL is required to accelerate a CW electron beam of 100mA to 10MeV. In this application, critical hardware components are not cavities but RF input couplers and HOM dampers. To demonstrate the feasibility, an injector cryomodule is designed and will be tested with beam in a prototype ERL (cERL).

Several combinations of number of cavity and cells per cavity were examined, and a three 2-cell cavity system was chosen for cERL. Each cavity is drove by two input couplers to reduce required power handling capacity and also to compensate coupler kick. HOM coupler scheme was chosen for HOM damping, and 5 HOM couplers are put on beam pipes of each cavity. Because of simplicity cavities are cooled by jacket scheme. Basic parameters of the cavity are summarized in Table 1, where the numbers in parentheses are for the planed ERL.

Table 1: Basic Cavity Parameters for a cERL injector

Frequency	1.3	GHz
Number of cell	2	
R / Q	205	Ω
Operating Gradient	10 (14.5)	MV / m
Beam Current	50 (100)	mA
Number of Input Coupler	2	
Coupler Power	58 (167)	kW
Coupler Coupling Q	4.5 (3.3)x 10^5	
Number of HOM coupler	5	
Operating Temperature	2	k

CAVITY

A 2-cell cavity is shown in Figure 1. It has a TESLA-like cell shape and larger beam pipe aperture of 88mm. Two fully equipped prototype cavities were fabricated and tested. The results are shown in Figure 2. In the cases of without HOM pick-up probes, the cavity gradient reached more than 40MV/m (red dots in Figure 2) with small electron loading in both cavities. The reason of low Q value is due to losses at beam pipe flanges made of stainless steel. In the cases of with HOM pick-up probes (blue dots in Figure 2), however, some thermal instability was observed in the #1 cavity at about 15 MV/m, where both Q and gradient decrease slowly. It is well known due to the heating of pick-up probes of HOM couplers. Heating of one HOM coupler was detected by thermometer at around 16 MV/m in the test of the #1 cavity, but finally we could keep 16 MV/m for 6 hours. In the #2 cavity test with HOM probes, unfortunately vacuum leak was happened at 14 MV/m but thermal instability was not observed.

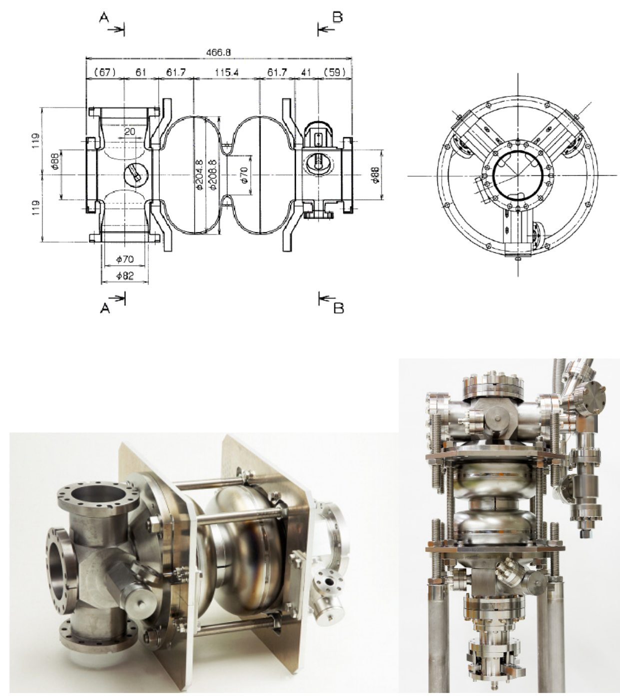

Figure 1: 2-cell Cavity

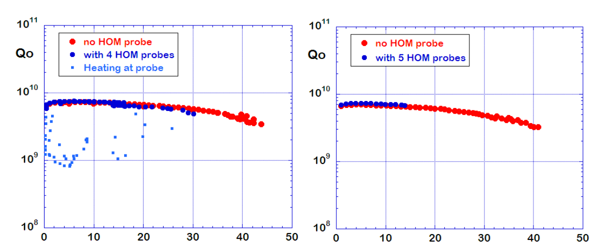

Figure 2: Vertical Test Results of Prototype Cavities.

INPUT COUPLER

RF input coupler is the most critical component in the high power application of the superconducting cavity. The most powerful CW coupler under operation is the KEK-B couplers, which has a coaxial disk type window developed for TRISTAN SC cavities [2]. We made scaled models to 1.3 GHz, as shown in Figure 3. Impedance of coaxial part is 41Ω, and the outer diameter is 82 mm.

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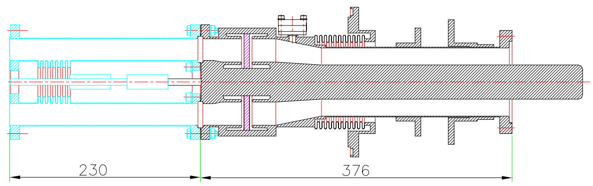

Figure 3: Input Coupler for Injector Cavities.

Couplers will be assembled to cavity in the clean-room before installation to a cryostat, so it should be short as possible. Then thermal intercept becomes difficult, and requires the 5k and 80k anchors at outer conductors. Inner conductors and the windows are cooled by water. High power test of a pair of couplers (Figure 4.) was performed using a newly developed 300kW CW klystron. Couplers were tested up to 100kW, so far. Farther test is planed in autumn.

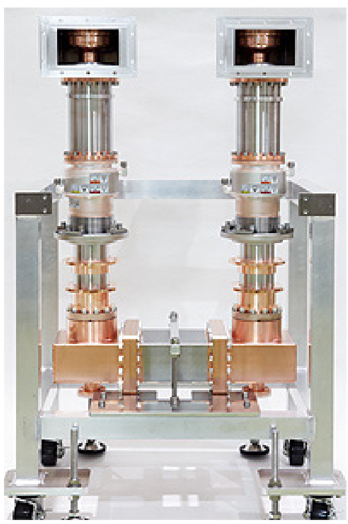

Figure 4: Prototype Input Coupler

HOM COUPLER

We decided to use HOM couplers instead of beam pipe HOM absorbers to damp HOMs, because absorbers are not well established in cold and they need extra drift space. TESLA –type HOM couplers are considered as the best choice, but it is well known that thermal instability appears above 10 MV/m in the CW operation. It is also well known that heating happens at pick-up proves of HOM couplers, but it is not yet understood why niobium antenna becomes normal conducting. One may expect that if the current density at antennae is reduced, the threshold gradient increases. TESLA HOM couplers are modified by introducing second stub and a boss as can be seen in Figure 5 [3]. Figure 6 shows the H field distribution of the modified HOM coupler, the H field is reduced by a half, to 2000 A/m at 15 MV/m. The first cold test was performed with these HOM couplers. After some processing, we could rise the gradient to 30 MV/m. Heating appeared in one HOM coupler, but we could keep the gradient of 16 MV/m for 6 hours. Major HOMs are summarized in Table 2.

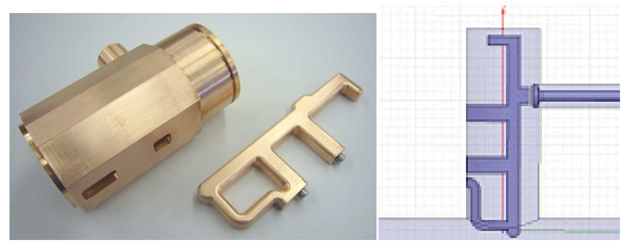

Figure 5: Two Stub HOM Coupler

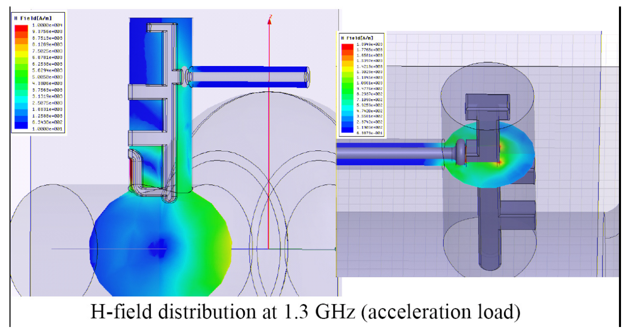

Figure 6: H-Field Distribution

Table 2: Major HOMs in 5 loop-type HOM couplers

Mode	Frequency	R / Q	Measured Q_L
TE111	1.54 GHz	0.59 Ω/cm^2	900
	1.60 GHz	1.8 Ω/cm^2	500
TM110	1.77 GHz	4.0 Ω/cm^2	400
	1.80 GHz	1.9 Ω/cm^2	3500
TM011	2.26 GHz	64 Ω	900
	2.30 GHz	12 Ω	1200
TM020	2.67 GHz	0.4 Ω	
	2.69 GHz	31 Ω	

FREQUENCY TUNER

We will use Slide Jack tuners [4, 5] which are used in STF cavities as is shown in Figure 7. Two pairs of wedge are set on both side of jacket cylinder flanges and driven by one shaft from outside of a cryostat. One piezo system is put in series with a slide jack tuner, and will be replaceable from a cryostat opening. Stroke of the tuner is listed in Table 3.

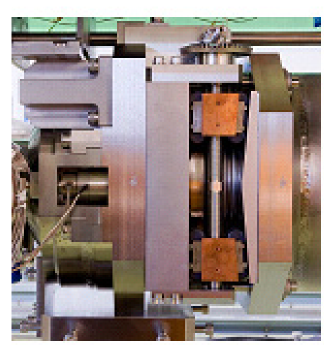

Figure 7: Slide Jack Tuner

Table 3: Stroke of the tuner

	Type	Stroke	Δf
Mechanical Tuner	Slide Jack	1mm	1.3MHz
Fine Tuner	Piezo	4μm	2.6kHz

CRYOSTAT

Figure 8 and 9 show a cryostat containing three 2-cell cavities. Final design is in progress. Cavities are dressed with He vessel made of Titanium, and magnetic shields are put inside of He vessel. The estimated cryogenic load in 100mA and 10MV operation is summarized in Table 4. As is seen from this table, it is critical to take dynamic load of input couplers and HOM power extraction cables. They will be anchored to 4.5k reservoir panels put on both side of cavities, which works as a thermal shield as well. Because of this difficulty the operating gradient may be lowered.

Table 4: Cryogenic Load per Cavity

	2k		4.5k	
	Static	Dynamic	Static	Dynamic
Cavity	0	6W	0	0
Input Coupler	2W	4W	8W	16W
HOM Cable	1W	7W	5W	14W
Beam Pipe	1W	0	2W	0
Others	5W	0	10W	0
Total	9W	17W	25W	30W

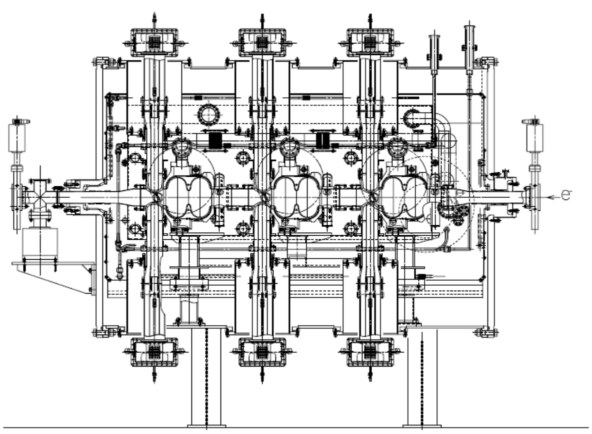

Figure 8: Injector Cryomodule

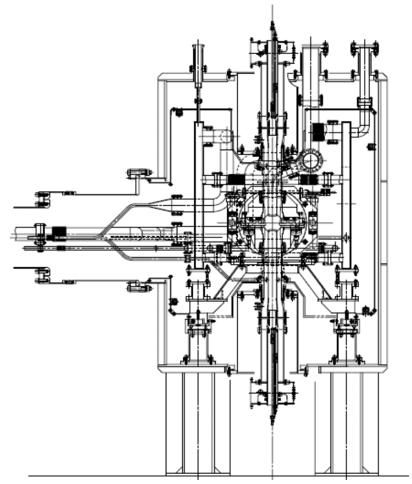

Figure 9: Injector Cryomodule

SUMMARY

Development of Injector cryomodule is in progress. Assembly of cryomodule is scheduled in late 2011. Depending on test results, the number of cavities for the real ERL may be increased to 4.

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