VERTICAL TEST RESULTS FOR ERL 9-CELL CAVITIES FOR COMPACT ERL PROJECT

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Abstract

Two ERL 9-cell cavities were fabricated for the cERL main linac cryomodule. A series of surface treatments were applied for the cavities. Low current final EP and careful flange assembly were applied for cavities in an effort to suppress field emissions. Vertical tests were performed for both cavities. Their field successfully reached to 25 MV/m without any field limitation. The Q-values were more than 1×10^{10} at 15 MV/m. Field emission onsets were 14 and 22 MV/m. Both cavities satisfied requirements for cERL main linac cavity. Details of vertical tests, with X-ray and temperature mapping data, are shown, in this paper.

INTRODUCTION

The Compact ERL (cERL) [1, 2] is a project to operate ERL test facility and now under construction in Japan. Its beam energy is 35-200 MeV and its beam current is 10-100mA. Main aim of the cERL project is demonstration of critical technologies needed for future multi GeV class ERL light sources. Development of superconducting cavity and cryomodule system is one of important issues.

For the first stage of cERL project, one main linac cryomodule [3] have been designed to accelerate electron beams up to 30 MeV by using two 9-cell cavities. Requirements for the cavities are following:

- Accelerating gradient 15~20 MV/m
- $Q_0 > 10^{10}$ at 15MV/m
- CW high current beam operation (> 100 mA)

Two ERL 9-cell superconducting cavities, ERL 9-cell #3 and #4 cavities, were fabricated under High Pressure Gas Safety Act in Japan. After a series of surface treatments, vertical tests were carried out to verify their performances. Cavity diagnostics had been also done using rotating type X-ray and temperature mapping system.

Construction of main linac cryomodule and its cooling tests are planned this year. Beam test of cERL project will start at next year.

ERL MAIN LINAC 9-CELL CAVITY

For the future ERL light sources, the most important point is damping of HOMs (higher order modes) to avoid BBU instabilities. KEK-ERL model-2 cavity [4] has optimized cell shapes for high current ERL operation. Large iris diameter and large beampipes can realize strong HOM suppression. Main parameters of cavity are listed in table 1.

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Table 1: Parameters for KEK-ERL Model-2 Cavity

Frequency	1.3GHz	Coupling	3.8 %
R_{sh}/Q	897 Ω	Geom.Fac.	289 Ω
E_{peak}/E_{acc}	3.0	H_{peak}/E_{acc}	42.5Oe/(MV/m)

One big challenge of ERL cavity is stable operation under high gradient CW mode. Because of large iris diameter, one demerit of cavity design is large E_{peak}/E_{acc} of 3.0. Thus, suppression of field emission is very important to reduce undesirable cryogenic losses and radiation dose.

HISTORY AND EXPERIMENTAL SETUP

History of the ERL 9-cell #3 and #4 cavities are shown in Table 2. Series of surface treatment were applied and two times of vertical tests were performed for each cavity. More than 98% of field flatness was obtained after each pre-tuning. Relatively low current EP (Electro polishing) of $32mA/cm^2$ and HPR (High Pressure Rinsing) by ultra-pure water of more than 10 hours were applied and flange assembly was carefully done to suppress field emission sources.

Table 2: History of ERL-9cell #3 and #4 Cavities

ERL 9-cell #3 cavity	ERL 9-cell #4 cavity
EP-1(125um) Annealing Pre-tuning EP-2(50um), Degreasing HPR, Assembly, Baking	EP-1(125um) Annealing Pre-tuning EP-2(50um), Degreasing HPR, Assembly, Baking
First vertical test	First vertical test
EP-2(20um), Degreasing HPR, Assembly, Baking	EP-2(30um), Degreasing HPR, Assembly, Baking
Second vertical test	Second vertical test

Vertical tests were done at KEK-STF vertical test area. A variable input coupler was mounted on bottom flange of the cavity. Stainless steel flanges were used for all cavity ports. During vertical tests radiation dose were measured using radiation monitors located on the top flange of the vertical test cryostat.

For the cavity diagnostics, array of carbon resisters and Si diodes were used to monitor temperature rise and X-ray behaviour just outside of the cavity wall. They rotate around the cavity and make details of 360 degree temperature and X-ray mappings. Especially obtained X-ray mapping can give powerful information about field emission, as shown below. The left of Figure 1 shows the

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layout of the rotating mapping system and the right shows a part of it. Total of 82 Si PIN diodes are mounted for monitoring nine cells [5].

During vertical tests, we limited Eacc up to 25 MV/m, in order to avoid unwanted burst-like accident which might sometimes happen at higher gradient and drastically degrade cavity performance by producing several field emission sources [6].

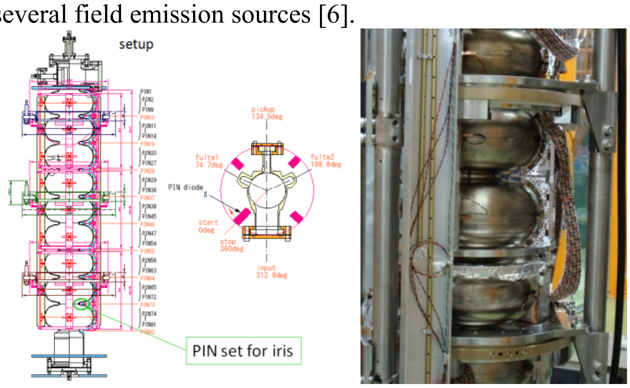

Figure 1: (Left) Layout of Si PIN diodes. (Right) Mapping system mounted on the cavity.

RESULTS FOR ERL 9-CELL #3 CAVITY

Two times of vertical tests were carried out for ERL 9-cell #3 cavity. Figure 2 shows the Q-E curve of the cavity final state.

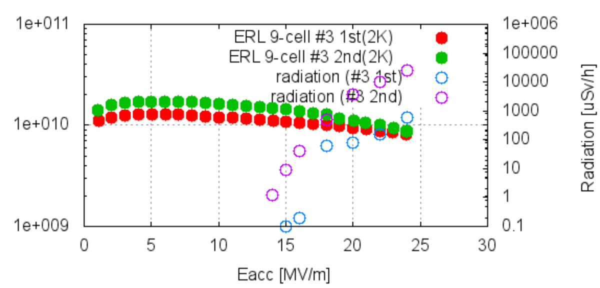

Figure 2: Vertical test results for ERL 9-cell #3 cavity. Left and right axes show Q_0 and radiation dose, respectively.

Results of First Vertical Test

As shown in Figure 2, the first vertical test for #3 cavity was successful. The Eacc reached to 25 MV/m without any limitation. Also Q-value was fine and cleared the requirement of $Q_0 > 10^{10}$ at 15 MV/m. During vertical test, quenches due to multipacting were observed from 16 to 22 MV/m, which is often seen for our cavities, and they were easily processed. The X-ray onset was around 15 MV/m, as shown in the figure 2.

Figure 3 shows X-ray mapping observed at 24 MV/m. It shows a sharp peak at 140 degree around 3-4 iris and broad signals around 320 degree from 5 to 9 irises. A hot spot at 315 degree around 6-7 iris is dummy signal, caused by enhancement due to a hole of stiffener ring. From our mapping data obtained so far and FISHPACT calculation [7], it is suggested that the position where sharp peak was observed or its opposite side is expected to be a emitter source position. Thus, we imagine that an emitter source exist around 140 or 320 degree of 3-4 iris.

Though the cavity performance was enough good for this test, unfortunate vacuum trouble occured after the vertical test forced to go another vertical test.

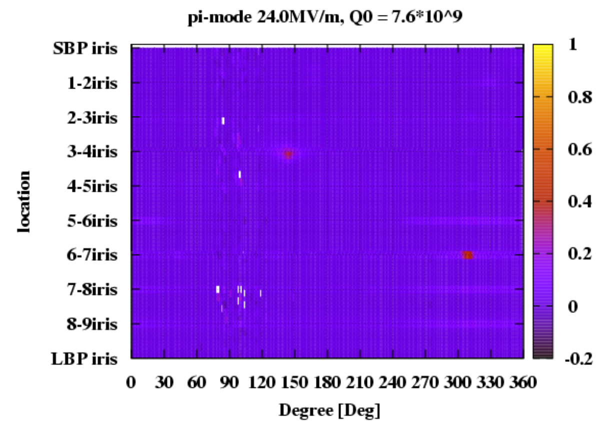

Figure 3: X-ray mapping results at Eacc = 24 MV/m, obtained at first vertical test of ERL 9-cell #3 cavity.

Results of Second Vertical Test

The second test was also fine. Eacc reached to 25 MV/m without limitation. The Q value also exceeds 10^{10} at 15 MV/m. The cavity satisfied cERL main linac requirement. During vertical test, small burst-like phenomena happened two times and amount of field emission was increased. Final X-ray onset was around 14 MV/m.

Figure 4 shows X-ray mapping observed at 22 MV/m. Broad signals are seen around 100 degree and 280 degree. If looking at details, sharp peaks can be found around 280 degree of 4-5 iris and 1-2 iris. A few emitters are expected to exist.

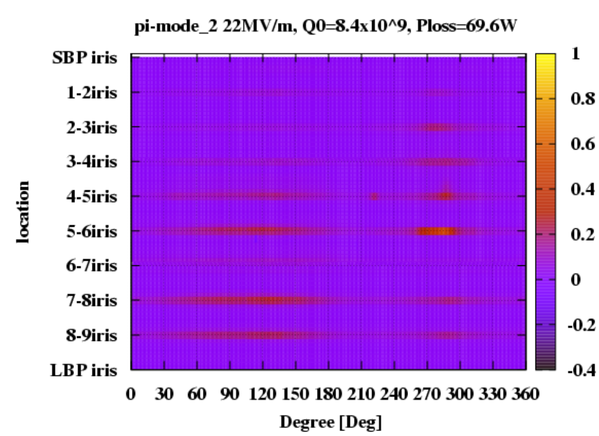

Figure 4: X-ray mapping results at Eacc = 22 MV/m, obtained at second vertical test of ERL 9-cell #3 cavity.

RESULTS FOR ERL 9-CELL #4 CAVITY

Two times of vertical tests were also carried out for ERL 9-cell #4 cavity. Figure 5 shows the Q-E curve of the cavity final state.

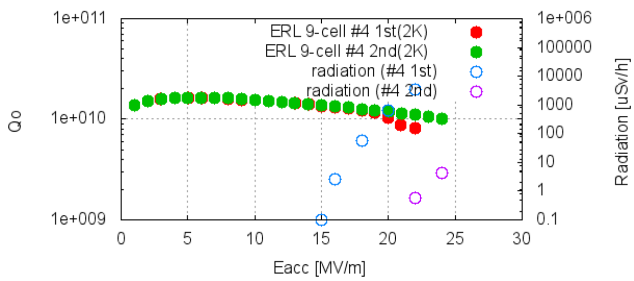

Figure 5: Vertical test results for ERL 9-cell #4 cavity. Left and right axes show Q_0 and radiation dose, respectively.

Results of First Vertical Test

At the first vertical test of #4 cavity, Eacc was limited to 22.7 MV/m. Temperature rise was observed around 224 degree at 1-cell equator, when quenches occurred. Figure 6 shows temperature mapping results, which was obtained during self-pulsing mode. After the vertical test, the cavity surface was inspected and a bump of ~10um height and ~200um width was found at the same position.

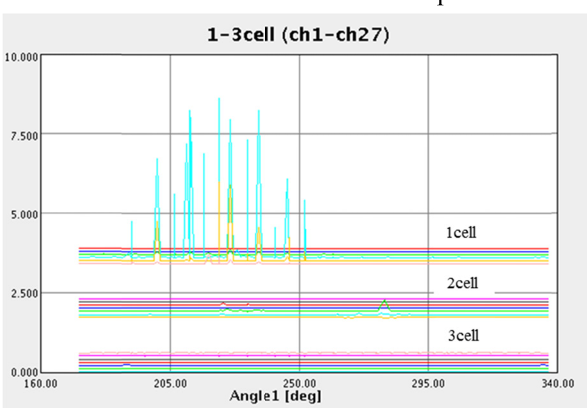

Figure 6: Temperature mapping results during self-pulsing at Eacc = 22.7 MV/m, obtained at first vertical test of ERL 9-cell #4 cavity.

Though the initial X-ray onset was 18 MV/m and detected X-ray signals were small, the situation suddenly became worth during processing. The final X-ray onset went down to 15 MV/m and the radiation of cavity final state at 20 MV/m became 20 times worse than initial state. From X-ray mapping, a sharp peak was observed around 360 degree at 1-2 iris and broad signals were observed around 180 degree from 5 to 9 irises.

Results of Second Vertical Test

The bump found after the first vertical test was locally grinded and disappeared, before the second vertical test. The results of second vertical test were excellent. Eacc reached to 25 MV/m without any limitation. The Q-value is enough good. Especially, no field emission was observed up to 22 MV/m. Figure 7 shows the X-ray mapping observed at 24 MV/m. Only a small signal was observed around 290 degree of 2-3 iris. Position of emitter source is imagined to be around 290 or 120 degree of 2-3 iris.

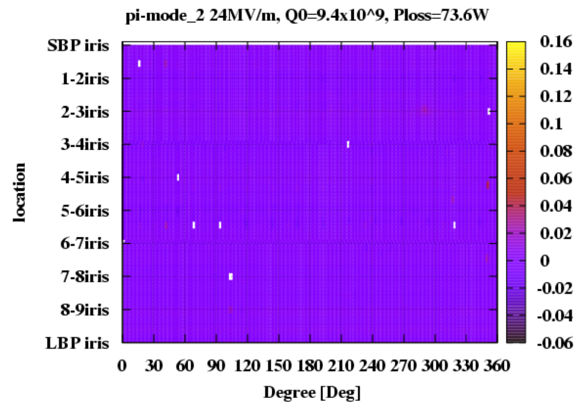

Figure 7: X-ray mapping results at Eacc = 24 MV/m, obtained at second vertical test for ERL 9-cell #4 cavity.

FUTURE PLAN

After successful vertical tests, He jackets were mounted on cavities. They will be installed into the cryomodule this summer, and cooling test and high power test will follow. The first beam from cERL will pass the cavities next year.

SUMMARY

Two ERL main linac 9-cell cavities were fabricated and surface treatment procedures were applied. Their performance was verified by vertical tests. They reached to 25 MV/m and satisfied the condition of $Q_0 > 10^{10}$ at 15 MV/m. Detailed X-ray and temperature mapping data obtained during vertical tests showed their powerful abilities. The cavities were already mounted with He jacket and will be installed into cryomodule.

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