MEASUREMENTS OF AN L-BAND THREE-CELL SUPERCONDUCTING CAVITY FABRICATED IN TOSHIBA

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Abstract

An L-band(1.3GHz) three-cell niobium cavity was fabricated in our company and measured at KEK. The maximum field gradient of $E_{acc,max}$=18MV/m was attained in the cold test. In the present paper, fabrication, pre-tuning, surface preparation on the cavity and the experimental results of the cavity are presented.

1 INTRODUCTION

Since 1995 the collaboration with KEK about superconducting cavities have been continued. Two L-band single-cell niobium cavities were fabricated in our company. Inner surface of two cavities were removed by barrel polishing[1] and electropolishing(EP)[2]. These cavities were annealed at 800°C and rinsed with high pressure deionized pure water[3]. After these treatments, two cavities were measured at low temperature. The maximum field gradient of $E_{acc,max}$>30MV/m in both single-cell cavities were attained[4].

An L-band three-cell cavity was fabricated and prepared by the same procedure as single-cell cavities and measured at low temperature.

2 FABRICATION

An L-band three-cell cavity was made from high purity niobium sheets(RRR=200) of 2.5mm thick. A series of fabricating processes such as forming by deep drawing of niobium sheets, trimming of formed half cells and electron beam welding were carried out. Beam tubes were made from rolled niobium sheets, then welded by electron beam. Joining of the iris of each cell were done by electron beam welding from the outside of the cavity. The fabricated three-cell cavity is shown in figure 1 and the specifications calculated by SUPERFISH code are summarized in table 1.

3 PRE-TUNING

After completing the cavity, a pre-tuning was performed to get flat field distribution strength in each cell. Figure 2 shows electric field distribution on beam axis before and after pre-tuning. After the pre-tuning, the field flatness in the π-mode was better than 96%. The cell to cell coupling as determined from the pass band modes frequencies was 2.5%.

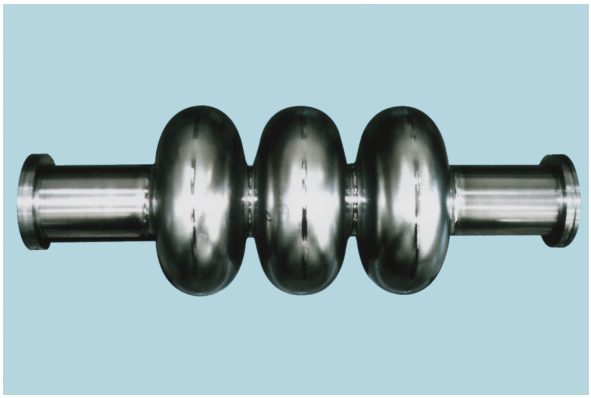

Figure 1 L-band three-cell superconducting cavity

Table 1 Three-cell cavity specifications calculated by SUPERFISH

Frequency	1299.23[MHz]
R_{sh}/Q	317[Ω]
G	274[Ω]
E_{sp}/E_{acc}	2.58
H_{sp}/E_{acc}	41.9[Oe/MV/m]
Coupling	2.3[%]

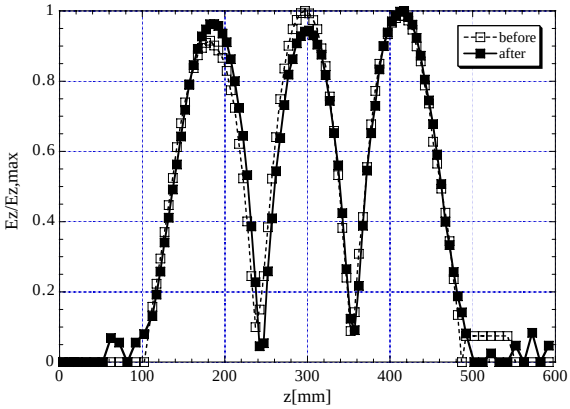

Figure 2 Electric field distribution before and after pre-tuning for three-cell cavity

4 EXPERIMENTAL RESULTS

In the three-cell cavity, performance tests were carried out three times. Surface preparations of the cavity and results of these tests are summarized in table 2. For the first test of this cavity, a inner surface layer of 80μm at the equator was removed by barrel polishing, and 100μm on the average was removed by EP. The cavity was annealed at 710°C for 5 hours with the titanium box to degas hydrogen, and rinsed with high pressure (85kgf/cm^2) deionized pure water(12MΩcm). These preparations were the same procedure as single-cell cavities. After the treatments, it was evacuated to 1x10^{-7}Pa and sealed in vacuum. The fast cool down to 4.2K was carried out in one hour after the pre-cooling of one night by liquid nitrogen. Three pass band modes were measured at 1.9K. The measured Q_0(unloaded Q value) of the cavity as a function of accelerating field gradient(E_{acc}) are shown in figure 3. In π-mode, marking with open square, Q_0 were 2x10^{10} and the residual surface resistance(R_{res}) was 9.1nΩ. The Q_0 did not degrade at high field, and the maximum field gradient($E_{peak,max}$) was limited to 38.7MV/m (E_{acc}=15.0MV/m). The X-ray appeared at E_{peak}=20MV/m. In (2/3)π-mode, as shown in figure 3 marking with open triangle, the X-ray began to be observed at E_{peak}=28MV/m, and $E_{peak,max}$ was limited to 34.5MV/m. In (1/3)π-mode, marking with open circle, Q_0 were sufficiently high at low field, however Q_0 began to drop remarkably and the X-ray appeared at E_{peak}=19MV/m. The maximum field was limited to 28.3MV/m. Measured frequencies of three pass band modes and coupling are summarized in table 3. Experimental results were almost in agreement with calculation.

In these measurements, the X-ray increased with E_{peak} increasing. This phenomenon was considered as field emission by surface contamination or defects. In the second test, to remove the surface irregularities, inner surface of the cavity was polished by 30μm on the average by EP. Following the polishing the hot rinsing (~60°C) and the high pressure rinsing of the cavity were carried out with deionized pure water. The hot rinsing had been used for TRISTAN superconducting cavities as a rinsing method to remove residual chemicals effectively. After the treatments, the cavity was evacuated to 1x10^{-7}Pa with baking and being evacuated during the experiment. The result of the measurement is shown in figure 4 marked with closed square. The maximum field of $E_{peak,max}$=46.3MV/m(E_{acc}=17.9MV/m) was measured at 1.9K, limited by the field emission, which started around E_{peak}=36MV/m. The residual surface resistance of R_{res}=14.7n• was large compared with the result of the first test.

For the third test of the cavity, a inner surface layer of 30μm on the average was removed by EP and the hot rinsing and the high pressure rinsing of the cavity were carried out with deionized pure water. In order to prevent field emission, the high pressure rinsing was carried out for a little bit longer time of 3 hours. The result of the

Table 2 Summary of the experimental results

Preparation	Measurements(π-mode)		
	Test	$E_{peak,max}$ [MV/m]	R_{res} [nΩ]
BP(80μm at eq.),EP(100μm), Anneal,HPR(2.5hr.)	1st.	38.7	9.1
EP(30μm),HR,HPR(2.5hr.)	2nd.	46.3	14.7
EP(30μm),HR,HPR(3hr.)	3rd.	28.6	13.2

BP : Barrel Polishing, EP : Electropolishing,
HPR : High Pressure Rinsing, HR : Hot Rinsing

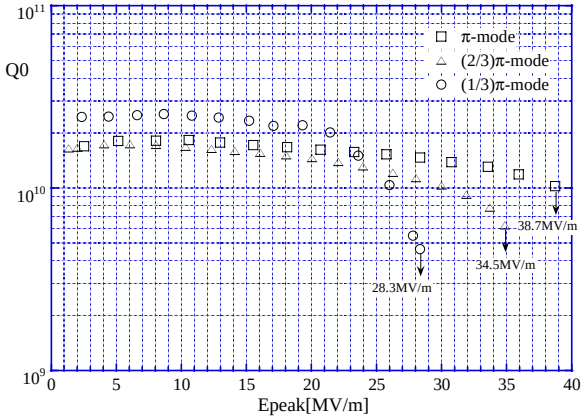

Figure 3 Q_0-E_{peak} plots of each mode on three-cell cavity

Table 3 Frequency of three pass band modes

	Calculated	Measured	
		room temp.	1.9K
(1/3)π-mode[MHz]	1269.76	1269.16	1270.58
(2/3)π-mode[MHz]	1288.67	1290.28	1292.05
π-mode[MHz]	1299.23	1301.06	1302.89
Coupling[%]	2.3	2.5	2.5

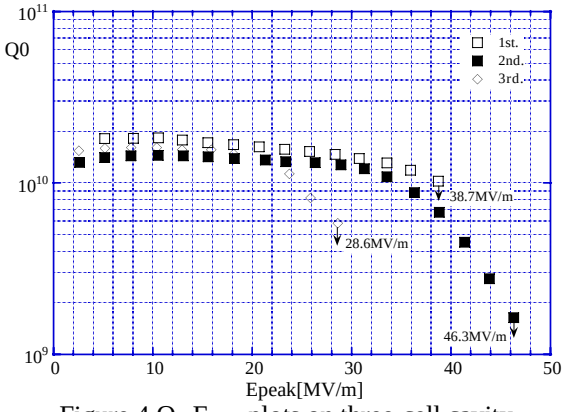

Figure 4 Q_0-E_{peak} plots on three-cell cavity

measurement is shown in figure 4 marked with open diamond. The maximum field of $E_{peak,max}$=28.6MV/m (E_{acc}=11.1MV/m) was measured at 1.8K, limited by the field emission, which started around E_{peak}=13MV/m. The residual surface resistance of R_{res}=13.2n• was almost the same as the result of the second test. However, the field emission started at lower field than its of the second test and the maximum field reduced remarkably. The causes of the field emission generated in these tests is not clear. Surface preparations and performance tests of the three-cell cavity will be continued to get the higher gradient ; $E_{acc,max}$>30MV/m.

5 CONCLUSION

An L-band three-cell niobium cavity was fabricated in our company and measured at KEK. The maximum field gradient of $E_{acc,max}$=18MV/m was limited by the field emission, though the cavity was fabricated and prepared by the same procedure as single-cell cavities achieved the maximum field of $E_{acc,max}$>30MV/m. Surface preparations and performance tests will be continued to get the higher gradient ; $E_{acc,max}$>30MV/m.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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