A NEW CAVITY DIAGNOSTIC SYSTEM FOR THE VERTICAL TEST OF 1.3GHZ SUPERCONDUCTING 9-CELL CAVITIES AT KEK-STF

Y. Yamamoto#, H. Hayano, E. Kako, S. Noguchi, M. Sato, T. Shishido, K. Umemori, K. Watanabe, KEK, Tsukuba, 305-0801, Japan,
H. Sakai, ISSP, Univ. of Tokyo, Kashiwa, 277-8581, Japan,
T.X. Zhao, TIPC, Beijing, 100080, China.

Abstract

A new cavity diagnostic system has been introduced for vertical testing of 9-cell L-band superconducting cavities at KEK-STF. The present system is based on approximately 300 carbon resistors for temperature-mapping (T-mapping), and approximately 40 PIN photo diodes for detecting emission of X-rays. While most of the sensors are attached to the cavity exterior in a pre-determined regular pattern, some sensors can be strategically placed at non-regular positions so as to watch the areas which are considered “suspicious” as per the surface inspection done prior to vertical testing (pinpoint attachment). Although the T-mapping system identified perfectly the heating location in every vertical test, there was no correlation between the heating location and the suspicious spot.

INTRODUCTION

The vertical testing has been routinely performed since October 2008 at KEK-STF [1]. The new cavity diagnostic system is introduced for every vertical test. The most important goal is to investigate whether there is a correlation between the heating location detected by T-mapping and the suspicious spot observed by the optical inspection camera [2]. Moreover, it is also important to identify the cause of the field limit by combining the results between T-mapping and the pass-band mode measurement, which modes are from $3\pi/9$ to π.

Each carbon resistor covers the area of 25mm x 25mm on the cavity surface. It is sufficient to catch the heating, because the heating usually expands to one fifth or sixth of the circumference on the equator region.

In this proceeding, the recent results of the T-mapping for AES#001, MHI#5 and MHI#6 cavities are reported. As the other interesting topics, the pre-heating phenomenon before the thermal quenching and the heating at the top flange, which is made by stainless steel, are reported.

CAVITY DIAGNOSTIC SYSTEM

The use of the carbon resistor for the identification of the heating location is a traditional way for the vertical test in SCRF field. In KEK-STF, the fixed-type T-mapping system is introduced and the number is about 300. Before the vertical test, the cavity surface is thoroughly investigated by the optical inspection camera and the location of the suspicious spots is identified. One carbon resistor is directly attached at each suspicious spot (pinpoint attachment). Figure 1 shows the photos of the cavity diagnostic system at KEK-STF.

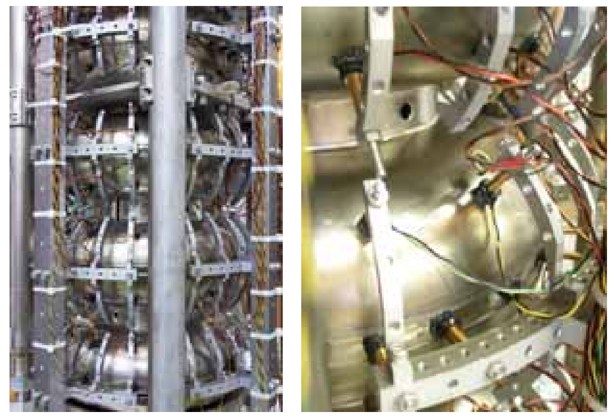

Figure 1: The cavity diagnostic system at STF.

Several PIN diodes are attached at the both end flanges for the detection of x-ray due to the field emission. Many PIN diodes will be attached around the stiffening ring in the future, although only 22 diodes are attached there now. This PIN diode system is under development.

CAUSES OF FIELD LIMIT

There are three causes of the cavity field limit in the followings. It is possible to distinguish between the thermal quenching and the field emission using the results of the T-mapping and the pass-band mode measurement.

Thermal Quenching

This is a clear and usual phenomenon which is generated by a defect or contamination. There is a good correlation between the results of T-mapping and the pass-band mode measurement, although any suspicious spot is not almost found at the heating location.

Field Emission

This is a significant problem which cause is not identified. There is no correlation between the results of T-mapping and the pass-band mode measurement. The heating is triggered by the electron bombardment due to the field emission.

Multipacting

Multipacting is easily overcome in one situation and it takes a long time to do it in other situation. If the RF conditioning is performed for a longer time, it is possibly overcome in the end.

#yasuchika.yamamoto@kek.jp

RESULT OF T-MAPPING

AES#001 Cavity

The performance tests for this cavity were done totally twice with the new T-mapping system. The heating location, where was already detected in FNAL, was observed by the optical inspection camera before the vertical test, and two suspicious spots were found there. Therefore, many additional resistors were attached to that location. The heating location in second and third vertical test was cell #3 in π mode, which was the same location as FNAL's result. Figure 2 shows the time trend graph and heating location for T-mapping at the third test. In the left figure, the blue line shows the transmit power from the cavity and ΔT means the temperature difference between the liquid helium and the heating location. The cell #3 was also heating in 5π/9, 6π/9 and 8π/9 except for π mode and the #5 and the #8 cell were heating in 3π/9.

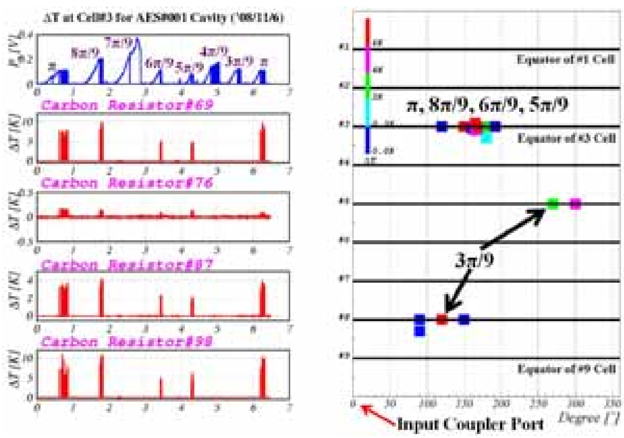

Figure 2: Trend graph and heating location from T-mapping result for AES#001 cavity at 3rd V.T.

MHI#5 Cavity

MHI#5 cavity was vertical-tested totally three times. Figure 3 shows the trend graph of the heating for the second and third test. In the second test, although some resistors including #213 were noisy, the heating signal was clearly observed. Figure 4 shows the T-mapping for three vertical tests and the electro-polished amount before each test. The heating at cell #5 certainly occurs in every vertical test when the gradient achieves around 30MV/m. The source of the heating at cell #5 still remains there in spite of performing the removal of averagely over 200µm from the surface by the electro-polish. Although the size should be sufficiently large to search by the inspection camera, it is strange that any suspicious spot is not also found there [3].

MHI#6 Cavity

The vertical test of MHI#6 was carried out totally four times including two tests for the study of the magnetic shield. Figure 5 shows the time trend graph and heating location for T-mapping at the first test. The limiting cell in π mode was #7 and the field was limited by the field emission. The gradient at cell #7 was 25.7MV/m for π

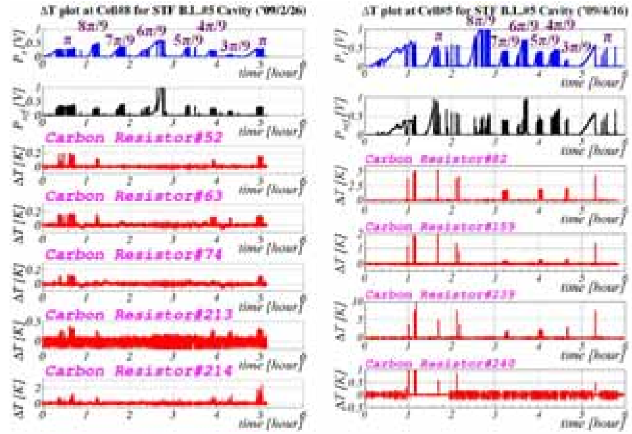

Figure 3: Trend graph of heating at 2nd (left) and 3rd (right) V.T. for MHI#5 cavity.

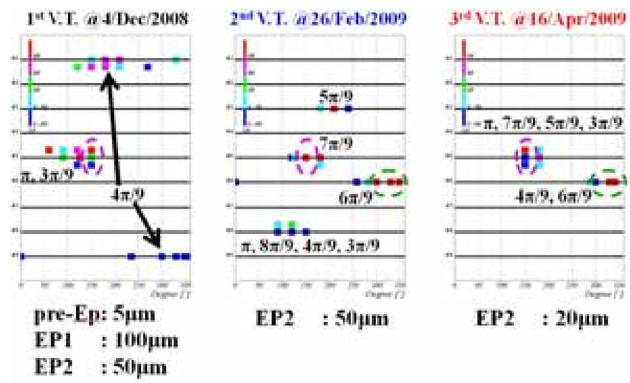

Figure 4: Changes of the heating location for MHI#5 cavity among three tests.

mode and 32.6MV/m for 5π/9 mode from the result of the pass-band measurement. Any heating at cell #7 was not observed for 5π/9 mode, although the field was higher. It is considered that the heavy field emission occurs in only π mode and the heating due to the electron bombardment was generated there.

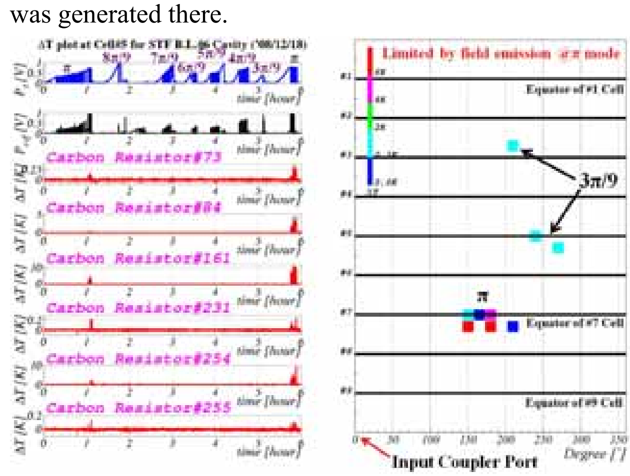

Figure 5: Trend graph and heating location from T-mapping result for MHI#6 cavity at 1st test.

Figure 6 shows the time trend graph and heating location for T-mapping in the fourth test. The cavity field was limited by the heating at cell #9 in every mode except for 3π/9 mode, which occurred around 20MV/m. The #5 cell was heating in 3π/9 mode, which was heating at the same location in the first test. From the left figure, it was found that the heating at cell #9 was gradually decreasing during the test. It took a very long time to do RF conditioning at each pass-band mode. If RF conditioning was done one more day, the barrier of the multipacting may be overcome. Normally, in the experience at STF, the barrier is easily overcome after a few thermal quenching.

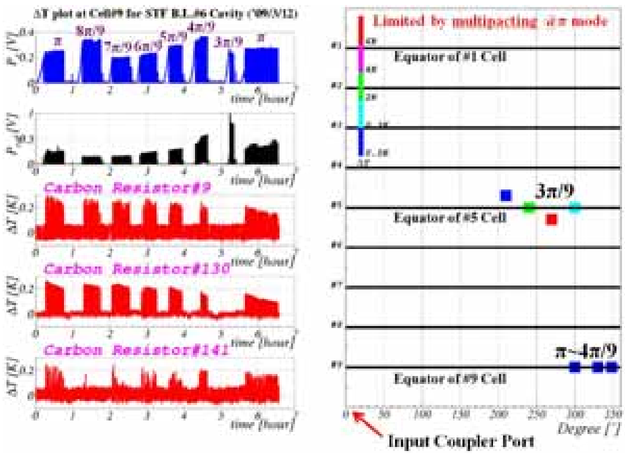

Figure 6: Trend graph and heating location from T-mapping result for MHI#6 cavity at 4th test.

OTHER TOPICS

Pre-heating Before Thermal Quenching

Before the thermal quenching, a little heating is occasionally observed with the x-ray emission. The situation is shown in the left of Figure 7. This heating is usually small, compared to that at the thermal quenching. The pre-heating location is limited, because only a few resistors respond to it.

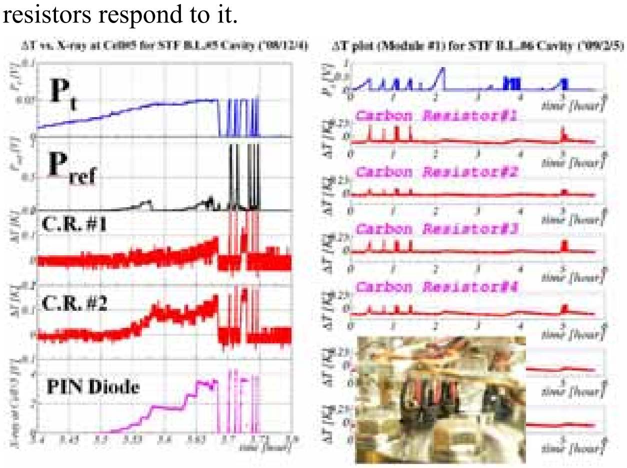

Figure 7: Example of the pre-heating before the thermal quenching (left) and the heating at the top flange (right).

Heating at Top Flange

Several carbon resistors were attached at the top flange of the beam pipe which is made by stainless steel. They detected a little heating at the thermal quenching as shown in Figure 7. This phenomenon is probably generated by the electron bombardment due to the field emission.

SUMMARY & FUTURE PLAN

The new T-mapping system perfectly detected the heating location at π mode in every vertical test at STF. Although the result of AES#001 cavity was very clear because of the consistency between the heating location and the suspicious spot, it was not a general case. For MHI#5 and #6 cavities, although the heating location was detected at every vertical test, any suspicious spot was not observed there. The summary of T-mapping result is shown in Table 1.

Table 1: Summary of T-mapping

Cavity	# of V.T.	$E_{acc,\,max}$ [MV/m]	Heating cell in π mode	Cause of field limit
AES#001	2nd	15.7	#3	Found defect
AES#001	3rd	21.8	#3	Found defect
MHI#5	1st	27.3	#5	Defect or contamination
MHI#5	2nd	19.7	#8	Defect or contamination
MHI#5	3rd	27.1	#5	Defect or contamination
MHI#6	1st	25.7	#7	Field emission
MHI#6	4th	19.6	#9	Multipacting

ACKNOWLEDGMENTS

The authors wish to express our special thanks to S. Mishra, B. Kephart, M. Champion and C. Ginsburg in FNAL for a loan of AES#001 cavity. The authors are indebted to K. Sennyu and H. Hara (MHI, Mitsubishi Heavy Industries) for the fabrication of the STF Baseline cavities. Special thanks are given to T. Suzuki and S. Fukuda (Nomura Plating Co., Ltd.), K. Nakamura and N. Tasaki (Assist Engineering Co.), and M. Sawabe at KEK for the surface preparation of these cavities, T. Okada and M. Iitake (k-VAC) for the assembly of the new T-mapping system.

REFERENCES

[1] Y. Yamamoto et al., “Recent Results of the Vertical Test for 1.3GHz Superconducting 9-cell Cavities at KEK-STF”, PAC’09, Vancouver, Canada, (2009) in these proceedings, TU5PFP074.
[2] Y. Iwashita et al., Phys. Rev. ST Accel. Beams 11, 093501 (2008).
[3] K. Watanabe, et al., “Recent Results of the Cavity Inspection for the Superconducting Cavities at KEK-STF”, PAC’09, Vancouver, Canada, (2009) in these proceedings, TU5PFP073.