RECENT RESULTS OF THE VERTICAL TEST FOR 1.3GHZ SUPERCONDUCTING 9-CELL CAVITIES AT KEK-STF

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Abstract

A new vertical test (VT) facility was built in KEK-STF (Superconducting rf Test Facility) and in operation since July/2008. In this paper, we discuss on the commissioning of this VT facility and its performance validation which was done in combination with that of the STF electro-polishing (EP) facility. Specifically, we report on the VTs that were so far made on three units of 9-cell cavities: AES#001 which was on loan from FNAL, MHI#5 and MHI#6 which were newly fabricated in Japan in 2007-2008. We discuss the performance and the limitation of the tested cavities and outline the directions of the next-stage of the R&D toward high-gradient L-band superconducting cavities to apply at ILC and elsewhere.

INTRODUCTION

The new VT facility was constructed for ILC (International Linear Collider) and ERL (Energy Recovery Linac) project in KEK-STF. After the pilot test using AES#001 cavity, the facility is routinely used for the VT of a few cavities, which number is totally seven times so far.

The important measurement method is the pass-band measurement and the T-mapping in the VT. By measuring the seven pass-band modes from $3\pi/9$ to π mode, the achievable gradient for each cell is obtained. On the other hand, the heating cell is identified from the T-mapping, which was newly introduced for the new VT facility and detected the heating location in every VT [1].

In this proceeding, the recent results of the VTs for AES#001, MHI#5 and MHI#6 are reported [2]. They are included Q_0 - E_{acc} curves, the radiation monitor and the achievable gradient for each cell. As the other interesting topics, Q_0 and Q_t degradation, and another pass-band mode excitation are discussed.

COMMISSIONING TEST OF VT FACILITY USING AES#001 CAVITY

This cavity was used for the commissioning test of the new VT facility in KEK-STF, which was rent from FNAL. After the pilot test which was performed for the system check, this cavity experienced the VTs twice as a performance test including one electro-polish (EP) process between them.

Figure 1 shows the Q_0 - E_{acc} curves and the radiation level for the two performance tests. After EP of 20μm, although the cavity performance was improved from 15.7 to 21.8MV/m, the heating location was same between them, which was #3 cell. The radiation level is usually measured at the top flange of the cryostat. Comparing it at the same gradient, it was drastically improved and the field emission was not also heavy.

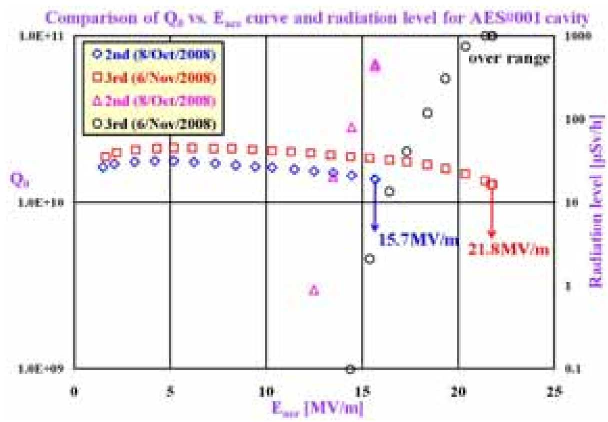

Figure 1: Q_0 - E_{acc} curves (square and diamond) and the radiation level (circle and triangle) for AES#001 cavity.

Figure 2 shows the Q_0 - $E_{acc\ @end\ cell}$ curves and the achievable gradient for each cell. The horizontal axis is the gradient measured at the end cell. Using the calculated field profile, the achievable gradient for each cell is obtained, as shown in the small figure. It is found that every cell except for #3 and #7 cells is achieved above 30MV/m. The sun mark shows the limiting cell in π mode.

This cavity was used for the system commissioning of EP and HPR facility at STF, except for the VT. After every test, it was sent back to FNAL on December 2008.

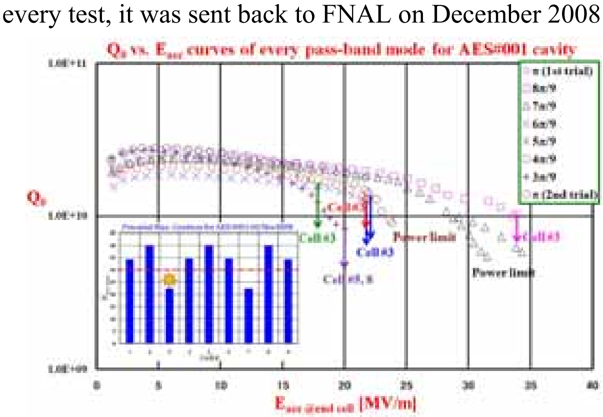

Figure 2: Q_0 - $E_{acc\ @end\ cell}$ curves and achievable gradient for each cell (small figure) at 2nd test.

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RESULTS OF MHI#5&#6 CAVITY

MHI#5 cavity experienced the VTs totally three times. The comparison of the Q_0 - E_{acc} curves and the radiation level among every test are shown in Figure 3 for π mode.

At the first test, MHI#5 had a heavy field emission and the limiting cell was #5. The accelerating gradient was drastically dropped to 19.7MV/m at the second one, although EP2 (50μm), H_2O_2 rinsing and HPR were performed. The limiting cell was changed from #5 to #8 and the radiation level was lower.

After the second test, the first ethanol rinsing was tried as a new cleaning process in STF. In the third test, the cavity performance was recovered to the original level and the radiation level at the same gradient was also much lower, as shown in Figure 3. The limiting cell returned to #5 again. Figure 4 shows the Q_0 - $E_{acc\ @end\ cell}$ curves of every pass-band mode from 3π/9 to π mode and the achievable gradient for each cell at the third VT. Every cell except for #5 achieved above 30MV/m at the third test.

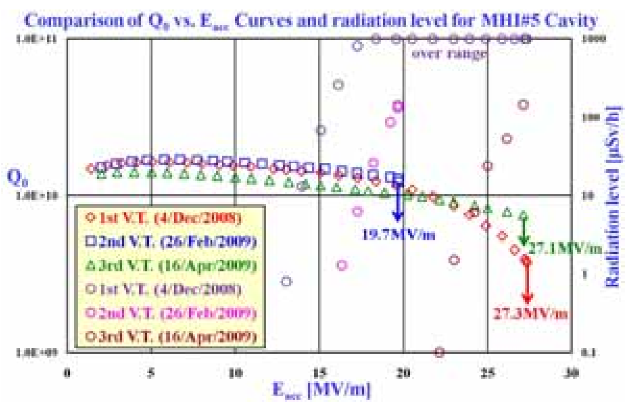

Figure 3: Q_0 - E_{acc} curves (square, diamond and triangle) and the radiation level (circles) for MHI#5 cavity.

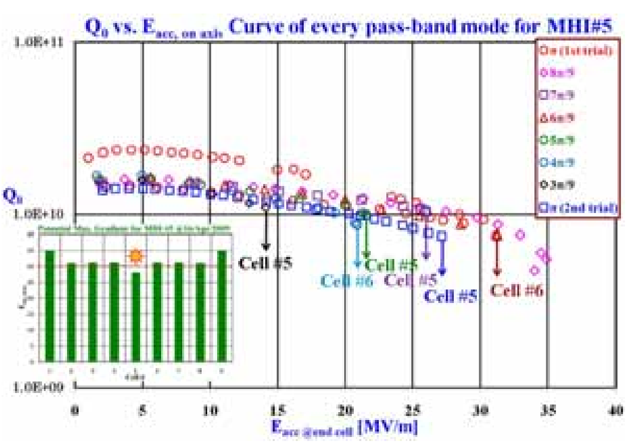

Figure 4: Q_0 - $E_{acc\ @end\ cell}$ curves and achievable gradient for each cell (small figure) at 3^{rd} test.

MHI#6 experienced the VTs totally four times including the studies of the magnetic shield at the second and third test. The comparison of the Q_0 - E_{acc} curves at the first and fourth test are shown with the radiation level in Figure 5 for π mode. There was no radiation at the fourth test. Similarly to MHI#5, the performance of MHI#6 was drastically dropped at the second test. The surface process was also completely same as MHI#5. At the first test, the achievable gradient for each cell was above 30MV/m. The limiting cell was changed from #7 at the first to #9 at the fourth test.

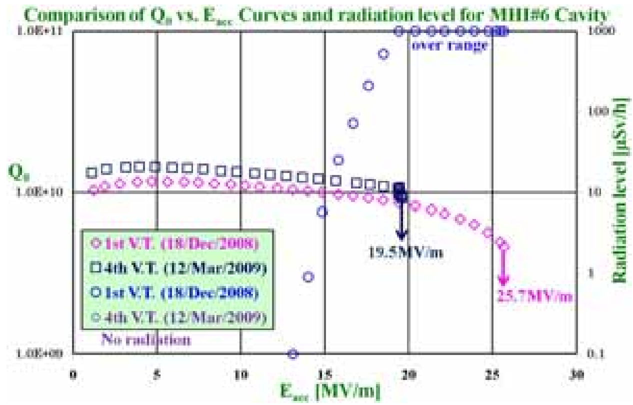

Figure 5: Q_0 - E_{acc} curves (square, diamond) and the radiation level (circles) for MHI#6 cavity.

Although it is not clear why the performance for the both cavities was dropped at the second test, it is apparent that their quality is almost same. In every VT for MHI#5 and #6 cavities, there was no correlation between the result of T-mapping and the suspicious spots [3].

OTHER TOPICS

Two interesting phenomena are reported in this section. One is the excitation of another pass-band mode. The other is Q_0 and Q_t degradation after many thermal quenching.

Excitation of Another Pass-band Mode

During the pass-band mode measurement, another pass-band mode different from the measured one, mainly 4π/9 and 6π/9, is sometimes excited as shown in Figure 6. The excited mode is only one in one situation and over two in the other situation. Although there is not a clear correlation for the radiation level, it is apparent that the electron emission is concerned with that. It is possible that the emitted electron is accelerated as the bunched beam on the cavity axis and the beam excites another mode different from the measured one. This situation is similar to that of a klystron.

Q_0 and Q_t Degradation

The phenomenon that Q_0 and Q_t gradually degrade after many thermal quenching is usually observed at KEK-STF, as shown in Figure 7. Q_0 depends on the temperature of the liquid helium and Q_t does not.

However, Q_t drops typically by 10-20% from the beginning to the end of one VT. This leads to the field degradation by 4%. This phenomenon is not understood at all.

On the other hand, although the temperature of the liquid helium is almost same at the low gradient in the first and second power rise, Q_0 drops by 50%. Therefore, this change of Q_0 is not dependent on the temperature of the liquid helium. It is possible that the trap of the magnetic field at the thermal quenching is concerned with it.

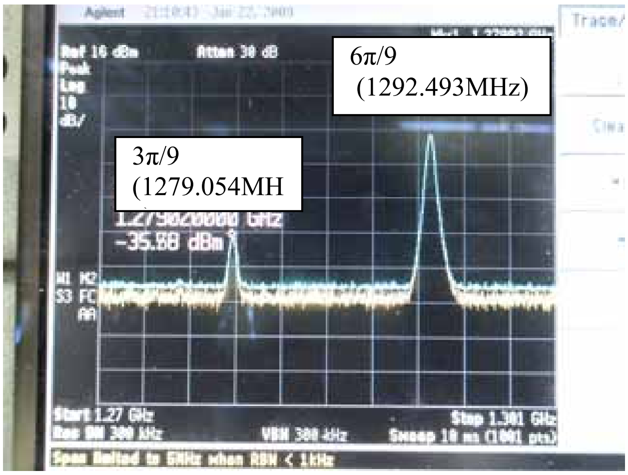

Figure 6: The excitation of another pass-band mode.

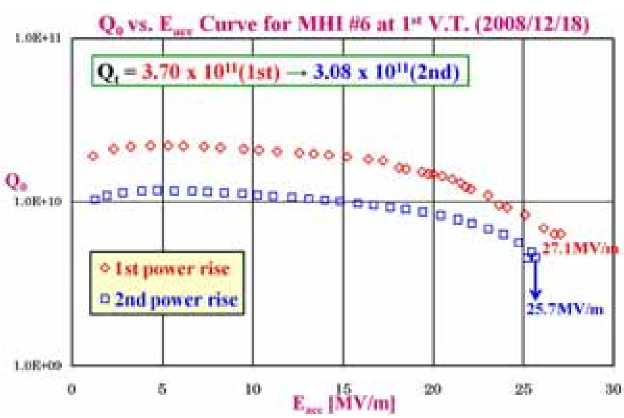

Figure 7: Q_0 and Q_t degradation during one VT.

SUMMARY & FUTURE PLAN

The VT is routinely carried out at KEK-STF since October/2008, including the surface process, the pre-tuning and the cavity inspection. Although the maximum accelerating gradient for every cavity was below 30MV/m, the cavity performance was improved, compared to the first four cavities (MHI#1–#4), as shown in Table 1. This shows that the quality of MHI#5 and #6 is not sufficient for the performance above 30MV/m and more improvement is necessary.

From June/2009, three new cavities (MHI#7-#9) will be measured at the VT facility. The method of the electron beam welding (EBW) is further improved for these cavities. Within these five cavities (MHI#5-#9), four ones will be selected for S1-Global project [4]. The Cryomodule test, which is satisfactory for ILC specification, will be done at STF in 2010 in collaboration with DESY, FNAL, INFN and KEK.

Table 1: Summary of Every VT at STF

Cavity	# of V.T.	$E_{acc,\,max}$ [MV/m]	Q_0	Radiation level [μSv/h]
AES#001	2nd	15.7	$1.37\text{x}10^{10}$	464
AES#001	3rd	21.8	$1.28\text{x}10^{10}$	>1000
MHI#5	1st	27.3	$3.72\text{x}10^{9}$	>1000
MHI#5	2nd	19.7	$1.28\text{x}10^{10}$	143
MHI#5	3rd	27.1	$7.53\text{x}10^{9}$	303
MHI#6	1st	25.7	$4.61\text{x}10^{9}$	>1000
MHI#6	4th	19.6	$9.14\text{x}10^{9}$	0

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