CONSTRUCTION AND BEAM OPEARTION OF CAPTURE CRYOMODULE FOR QUANTUM BEAM EXPERIMENTS AT KEK-STF

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Abstract

Construction of capture cryomodule for Quantum Beam Project [1] has started since September, and finished by the end of December in 2011 at KEK-STF. Two cavities (MHI#12, #13), which reached ILC specification ($0.8x10^{10}$ at 35MV/m) at the vertical test [2], were installed into a short cryomodule with improved input couplers. Slide-Jack tuner was attached at different position (center or end of helium jacket) for each cavity same as S1-Global [3]. From February 2012, this cryomodule was cooled down to 2K, and the high power test started including check of the cavity/coupler/tuner performance, LFD measurement, LFD compensation by Piezo, dynamic loss measurement and so on. From April, the beam commissioning started with a small beam current and the maximum beam energy of 40MeV. During the beam commissioning, two cavities are being operated stably without any trouble at the accelerating gradient of 15-20MV/m. In this report, the test results of various performances at the Quantum Beam Project will be presented in detail.

INTRODUCTION

In S1-Global, the cavity/coupler/tuner performance, the Lorentz Force Detuning (LFD), the LFD compensation by Piezo and the dynamic heat loss were evaluated through the various experiments "without beam". On the other hand, in Quantum Beam Project, the main purpose is the stable operation of one cryomodule equipped with two cavities (MHI#12 and #13) "with beam", although the same experiments were also carried out without beam. For the beam operation, the alignment is also important during the construction of the cryomodule including the cavity string. The operating gradient during the beam commissioning is 20MV/m for each cavity, and the control system is only the Feed-Back loop, not including Piezo, due to the small effect by the LFD.

CONSTRUCTION AND INSTALLATION OF CRYOMODULE AT STF

The construction of the cryomodule at STF started from October/2011. After the string assembly of two cavities in the clean room, the performance of the Slide-Jack tuner at the room temperature was checked thoroughly. At the attachment the cavity string to the gas return pipe, the alignment was carried out to be below 300μm (ILC specification) as the position error [4]. After the complete of the connection of every helium line, the cryomodule was undergone the High Pressure Code (HPC) by KHK [5], because this cryomodule is operated "legally" in Japan. The installation into the STF tunnel was done on November, and set to the beam line without any problem. Figure 1 shows the status of the construction and the installation into the tunnel.

Figure 1: Status of construction and installation in Quantum Beam Project.

COLD TESTS OF THE CRYOMODULE

Cool-down of cryomodule started from 20/Feb in 2012, and low power measurement for two cavities was done from 6/Mar to 16/Mar. High power test including dynamic heat loss measurement was carried out from 22/Mar to 11/Apr. The contents of these measurements were considerably limited due to the schedule of the radiation safety check by a government official.

Low Power RF Tests

In the low power RF test, the most important thing is the tuner drive test. Moreover, in Quantum Beam Project, the cavity frequency should be set to 1300.000MHz precisely due to the beam operation. The tuner drive test using the remote control system was finished successfully for two cavities. Figure 2 shows the plot of the cavity frequency vs. number of rotation.

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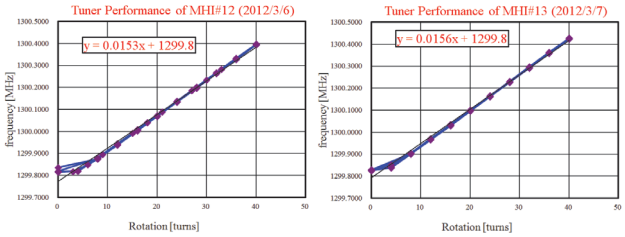

Figure 2: The result of the drive test for the motor tuner at low power.

For the rise-up time of 500μs, the optimum coupling of the variable input coupler should be set to 3.0 x 10^6 for Q_L. However, the variable coupler of MHI#12 could not be set to 3.0 x 10^6 as shown in Figure 3, because the change of the variable coupler caused the change of the tuner load. This means any deformation occurred in the cavity package. Therefore, by using the phase shifter in the waveguide system, Q_L of MHI#12 was set to 3.0 x 10^6.

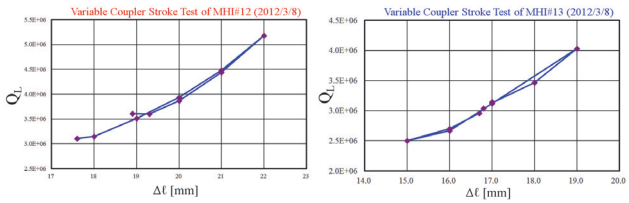

Figure 3: The Q_L stroke of variable input coupler.

Cavity Performance and Degradation

After the low power tests, the cavity conditioning was done to check the maximum gradient in the cryomodule test. Consequently, MHI#13 had the almost same performance (32MV/m) as the vertical test, and on the other hand, MHI#12 experienced the considerable performance drop (41 → 31MV/m), as shown in Figure 4. In S1-Global, the performance of MHI#5 dropped due to the miss-operation of F.B. system by LLRF control [6]. However, the cause of the performance drop for MHI#12 is unknown at present. After STF-2, the inner surface of this cavity will be inspected by Kyoto camera [7].

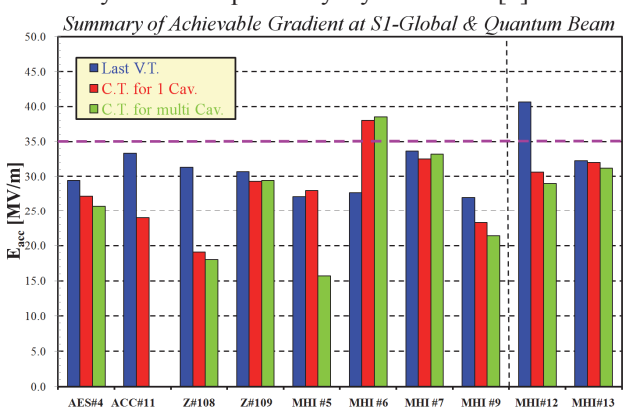

Figure 4: Comparison of maximum gradient for vertical and cryomodule test between S1-Global and Quantum Beam Project.

LFD Measurement & Compensation

In STF, for the LFD measurement, the pulse-shortening method by the automatic data taking system has been used since S1-Global. Figure 5 shows the result of the LFD measurement at the various gradients for MHI#12 and #13 with each step of 50 μs. For the evaluation of the elongation factor, the relation of $\Delta f = k \cdot E_{acc}^2$ (k: elongation factor [Hz/(MV/m)^2]) is used. Figure 6 shows the comparison of the elongation factor for every cavity used in S1-Global and Quantum Beam Project. MHI#12 and #13 have the smaller elongation factor in every time range.

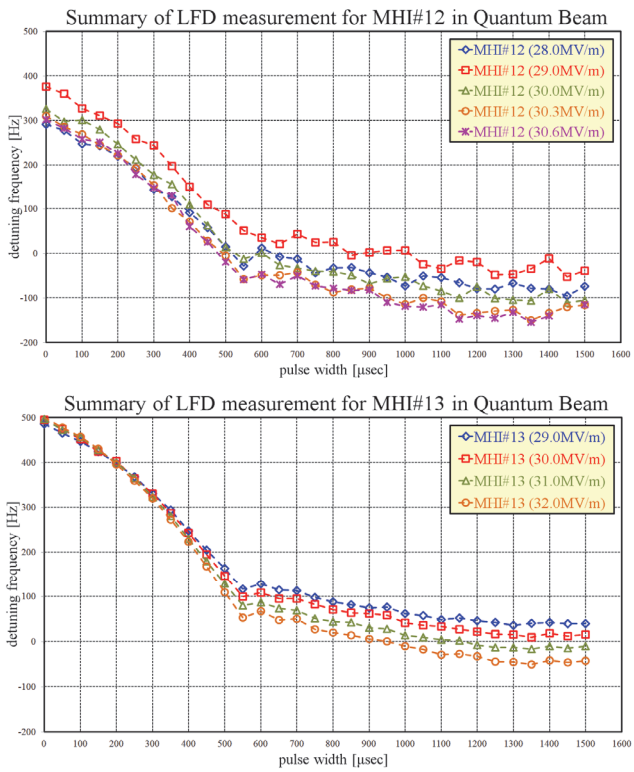

Figure 5: The result of LFD measurement at the various gradient for MHI#12 and #13.

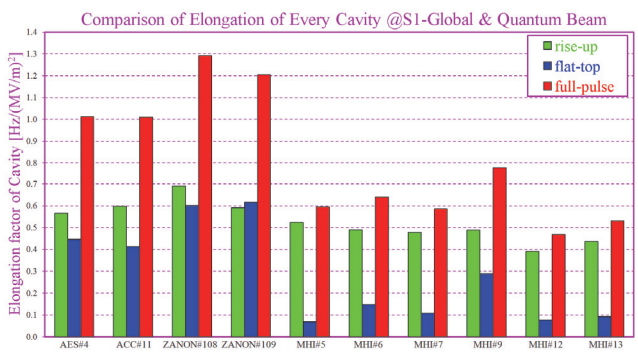

Figure 6: Comparison of the elongation factor in rise-up, flat-top and full-pulse range at S1-Global and Quantum Beam Project.

In the LFD compensation, a pulse corresponding to one period of a sine curve is applied to piezo before the RF pulse. By setting four adjustable parameters for the piezo drive, that is, drive frequency, delay time, pulse height,

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and pulse offset properly, it is possible to compensate the LFD effect. The results of the LFD compensation by the Piezo are shown in Figure 7. The peak-to-peak of Δf at the flat-top region is below 60Hz for these cavities.

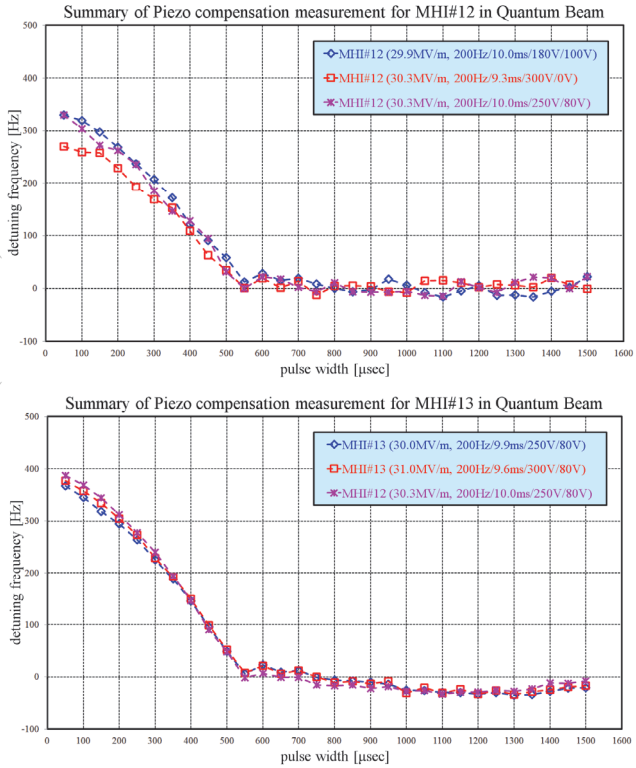

Figure 7: The results of the LFD compensation by Piezo.

BEAM COMMISSIONING

From 12/Apr, the beam commissioning started, and the electron beam went through the capture cryomodule without any problem [8]. At present, the problem is that the radiation level is considerably high at the beam dump in spite of much lower beam current for the operation condition of the laser Compton experiment. In the near future, much more concrete and lead shielding will be put around the beam dump. The experiment will be started from June, and kept by the end of this year.

SUMMARY

In Quantum Beam Project, the experiment for the capture cryomodule was finished and the beam commissioning started. During the cryomodule test, the significant problem occurred, which is the performance degradation of MHI#12 by the unknown cause. On the other hand, both tuners worked without any problem, and the cavity frequency was set to 1300.000MHz. During the high power test and the beam commissioning, the capture cryomodule including two cavities was operated stably. In the near future, more radiation shielding will be put around the beam dump due to higher radiation level.

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