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MECHANICAL VIBRATION SEARCH OF COMPACT ERL MAIN LINAC SUPERCONDUCTING CAVITIES IN CRYOMODULE

M. Satoh#, K. Enami, T. Furuya, S. Michizono, T. Miura, F. Qiu, H. Sakai, K. Shinoe, K. Umemori, KEK, Ibaraki, Japan
M. Sawamura, JAEA, Ibaraki, Japan
E. Cenni, Sokendai, Ibaraki, Japan

Abstract

For the main linac of ERL, high loaded Q (Q_L) operation is desirable to reduce the input generator power. In such operation mode, the suppression of the micophonics is important to stabilize RF amplitude and phase. One of reasons which causes microphonics is mechanical vibration, which changes the cavity frequency. The vibrations of the cavities, the cryomodule and the floor were investigated and compared with the microphnics data taken during cERL operation.

INTRODUCTION

The cryomodule (CM) of cERL main linac (ML) has a couple of 9-cell cavities (Cav1 and Cav2) and was started to assemble from July 2012 and installed in the ERL development facility in October 2012. The operation of cERL was started from December 2013.

The operation of the ML cavities are controlled by digital feedback (FB) of the low level RF system (LLRF), which provides the stabilization of RF amplitude and phase, whose target values are amplitude 0.1% and phase 0.1deg in cERL. The value of Q_L in cERL can be set on $1*10^7$~$4*10^7$, the band width (FWHM) is 32.5Hz~130Hz and it is important to suppress the microphonics.

In the following sections, only Cav1 will be mentioned because the two ML cavities have almost same tendency for some kind of vibration exams as following sections.

Some devices were used in the vibration measurements. A piezo actuator and a capacitive distance meter, MicroSence4830 (MS), directly observe the displacement, and the RF phase difference between the input power into a cavity (Pin) and the transmitted power from the cavity (Pt). FFT analyser (Agilent 35670A) was used for data taking. This analyser offers two modes for data taking. One method is the forced oscillation technique ("FOT") mode and the other is "free run" mode. In FOT, a piezo actuator is used as driver of forced vibration by sweeping frequency and another sensor is used to catch the amplitude of the only same vibration frequency under sweeping. the FFT analyzer records magnitude, the ratio of the sensor voltage divided by the driver voltage.

LLRF MICROPHONICS MEASUREMENT

The microphnics of Cav1 were measured on LLRF during cERL operation as shown in Fig1 [1]. There are FFT data of Pt amplitude and phase with FB or without FB, respectively. The horizontal axes show frequency components. Some vibration components are in the left figure in which FB is not applied, and are suppressed in the right with FB. 15Hz and 50Hz are dominant, others are 78Hz, 95Hz, 100Hz, 147Hz, 155Hz, 180Hz, 187Hz.

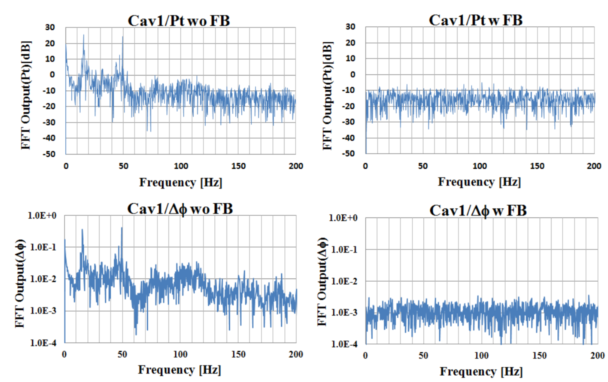

Figure 1: Microphonics of LLRF.

OFF LINE TEST

Off line test was held in order to identify the mechanical resonances of a 9-cell cavity in May 2012 as shown in Fig2, which was measured by using FOT mode [2]. Transversal movements were observed by perpendicularly pushing the equator of the end cell of the cavity by using a piezo actuator and longitudinal movements were observed by pushing the end flange of a cavity in the axis direction. When sweep frequency would match one of the resonance frequencies of the cavity, the amplitudes of every cell were measured in both of the longitudinal direction and the transversal direction by using the capacitive sensor, MS.

The resonant frequencies, 58Hz (T1), 124Hz (L1), 147Hz (T2) and 260Hz (T3) were observed as shown in Fig3. These are the specific frequencies of a 9-cell cavity.

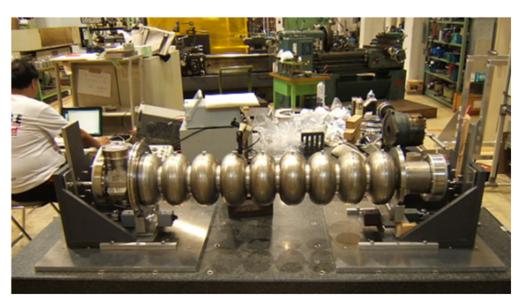

Figure 2: Off Line Test.

#masato.satoh@kek.jp

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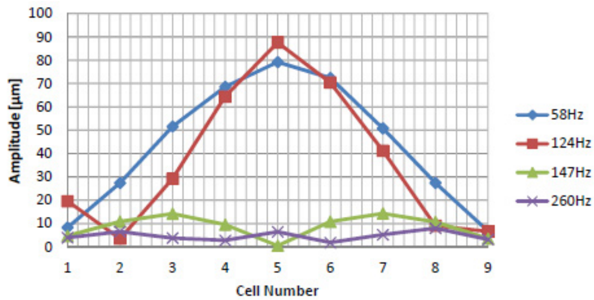

Figure 3: Measured amplitude on 9-cell cavity.

CRYOMODULE TEST

Mechanical Vibration on Cav1 in CM

After assembling CM, the vibration measurements of the cavities were carried out in CM. The condition of the measurement setup is shown in Fig4.

A piezo actuator can be used as both of a driver and a sensor of vibration, FOT between Piezo1 driver and Piezo2 sensor was done as shown in Fig5. The magnitude in Fig5 has already mentioned in “INTRODUCTION”. The major frequency components are 50Hz, 123Hz, 184Hz, 206Hz, 247Hz, 283Hz, and 122Hz is L1 mode of the cavity specific frequency.

The Free run measurement of Piezo1 is shown in Fig6. 50Hs is the dominant peak in Fig.6. The spectrum has some peaks, 12Hz, 20Hz, 28Hz, 37Hz, 100Hz, 110Hz, 122Hz and 148Hz

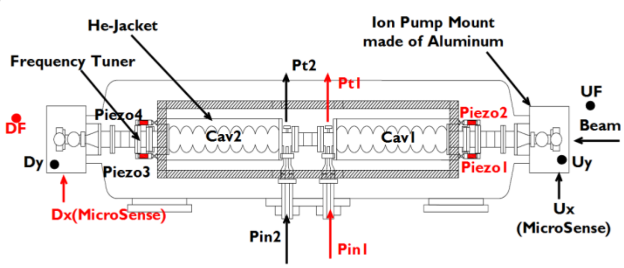

Figure 4: Cryomodule and Measurement Elements.

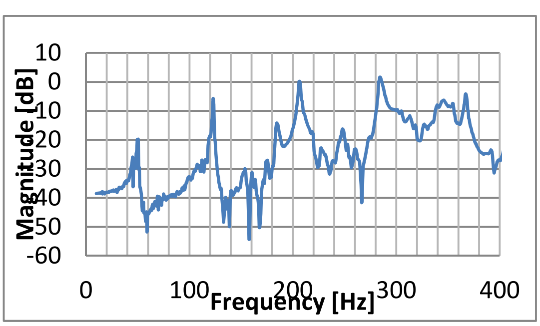

Figure 5: FOT of Piezo1 and Piezo2 in CM.

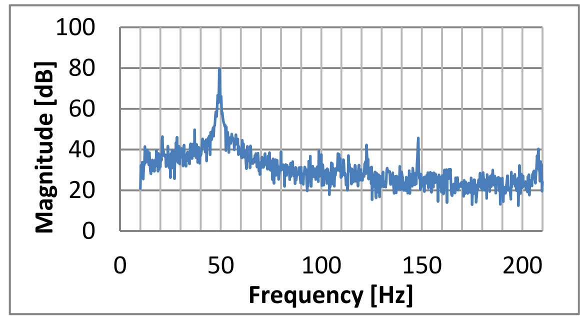

Figure 6: Free run of Piezo1 in CM.

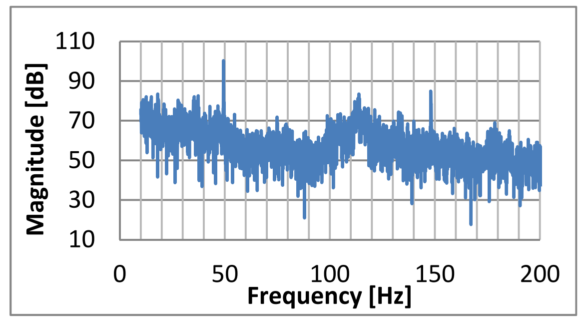

Figure 7: Free run of Δϕ in low RF power.

Piezo1 in Fig6 catches the real mechanical vibration but it did not equal to the meachnical vibration of Cav1.In order to measure the real michrophics to the phase of Cav1 more precisely . We directly measure the RF phase difference (Δϕ) between very low input power to cavity (Pin1) and transmitted power from cavity (Pt1) in Fig4 without high power source and no beam operation. First the free run measurement was carried out as shown in Fig7. There are peaks in Fig7, 18Hz, 27Hz, 35Hz, 50Hz, 114Hz, 132Hz, 150Hz, 178Hz and 185Hz.

Another RF measurement shown in Fig8 was carried out by FOT, which the forced vibration was driven by Piezo1 and Δϕ(Pin1,Pt1) was observed. There are only two peaks in Fig8, 115Hz and 187Hz.

Vibration of Floor and Cryomodule

The vibrations of CM and the floor were observed at six points in Fig4. But the exams about only Dx and DF are introduced here because the downstream of CM comparatively has stronger vibrations than the upstream

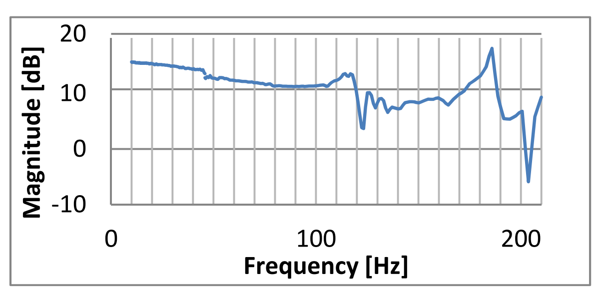

Figure 8: FOT of Piezo1 and Δϕ in CM.

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does. Dx is on the downstream of CM and the perpendicular direction to the beam axis, and DF is at the downstream floor and the vertical direction to the floor. MS was set on these points, and the free run measurements were carried out.

The vibration spectrum of DF is shown in Fig9. A rotary pump (RP) is under CM and RP makes certain frequencies increase. There are peaks, 13Hz, 18Hz, 25Hz, 35Hz, 50Hz, 74Hz, 87Hz, 100Hz, 124Hz, 150Hz, 180Hz. Especially 50Hz, 100Hz, 150Hz are suspected to concern to the rotation speed of RP. 180Hz is strongly enhanced in RP/ON.

The CM vibration spectrum in the state of RP/ON is shown in Fig10. There are peaks, 10Hz, 24Hz, 30Hz, 37Hz, 50Hz, 63Hz, 74Hz, 87Hz, 94Hz, 100Hz, 173Hz, 184Hz.

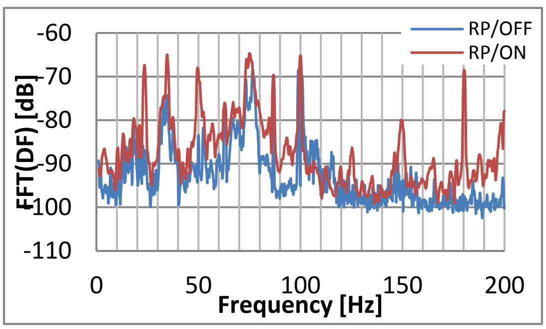

Figure 9: Free run of MS at DF.

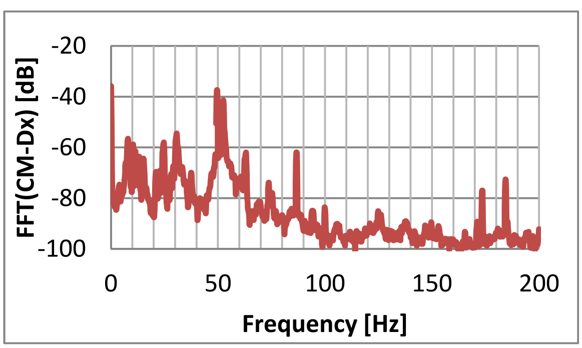

Figure 10: Free run of MS at Dx on CM.

COMPARISON OF MICROPHONICS TO MEASUREMENT DATA

The various vibration measurements were held and the results of those measurements have to be compared with LLRF data in order to know where the vibrations come from and what is vibrating. All frequency components already picked up in previous sections will be summarized as shown in Table1. The relations between the components can be investigated by the frequencies summarized every each measurement. The similar frequencies will be bundled into the same frequency category. Table1 is distinguished with three colours, the green means microphonics frequencies, the yellows are the specific frequencies of a 9-cell cavity at the off line test and the blues are the common frequencies between microphnics and a 9-cell cavity. Table1 shows that the specific frequencies of a 9-cell cavity would not contribute to the microphonics very well, and the all components of the microphonics are included in CM vibration and the floor vibration. More detailed analysis and measurements are now underway to know where the vibration source like RP was.

Table 1: Comparison Among Each Measurement

[Hz]	LLRF Fig1	Off Line Fig3	FOT Fig5	Free Fig6	Free−ϕ Fig7	FOT−ϕ Fig8	Floor Fig9	CM Fig10
10~15	◎	×	×	○		×	○	○
18~24	×	×	×	○	○	×	○	○
25~30	×	×	×	○	○	×	○	○
35~37	×	×	×	○	○	×	○	○
50	◎	×	○	○	○	×	○	○
58	×	○	×	×	×	×	×	×
63	×	×	×	×	×	×	×	○
74~78	○	×	×	×	×	×	○	○
87	×	×	×	×	×	×	○	○
94	○	×	×	×	×	×	×	○
100	○	×	×	○	×	×	○	○
110~115	×	×	×	○	○	○	×	×
122~124	×	○	○	○	×	×	○	×
132	×	×	×	×	○	×	×	×
147	○	○	×	○	×	×	×	×
150	○	Unknown	×	×	○	×	○	×
173	×	Unknown	×	×	×	×	×	○
178~180	○	Unknown	×	×	○	×	×	○
184~186	○	Unknown	×	×	○	○	×	○

SUMMARY

The microphonics appears in LLRF and especially has two dominant frequencies, 15Hz and 50Hz. And CM and the floor are main candidates of the vibration sources of 15Hz and 50Hz. And the specific frequencies of a 9-cell cavity would not contribute to the the microphonics on LLRF.

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[2] M. Satoh et al., “Mechanical oscillation Measurement of cERL Main Cavity”, Annual Meeting of Particle Accelerator Society of Japan, Nagoya, 2013.