MEASUREMENTS OF CAVITY MISALIGNMENT BY BEAM INDUCED HOM EXCITED IN 9-CELL SUPERCONDUCTING CAVITIES

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Abstract

Detection of cavity misalignment in the ILC superconducting cavities inside of the cryomodules can be done by using beam induced Higher Order Modes (HOM). It is beneficial to identify possible source of emittance growth by cavity misalignment.

Beam pipe modes which are localized in both ends of the cavity and TE111 1/9 pi mode which is localized in the center of the cavity are focused in this research. Deviations of these electrical centers from beam trajectory reference indicate cavity misalignment and bending. We measured beam-induced HOM in STF cavities of the STF accelerator at KEK in 2012 – 2013 [1] and TESLA cavities of FLASH at DESY in 2013 [2]. We could identify beam pipe modes and TE111 1/9 pi mode in STF cavities and TESLA cavities at around 2.1 GHz and 1.6 GHz, both of which were very small signals. In addition, we have measured beam induced HOM signals at FLASH in May 2014. We discuss this measurement in this paper.

Furthermore the electrical centers of these beam pipe mode are studied by stretched wire method, beads perturbation method and simulations by HFSS 12 [3]. The results of these measurements and simulations are also summarized.

BEAM INDUCED HOM MEASUREMENT

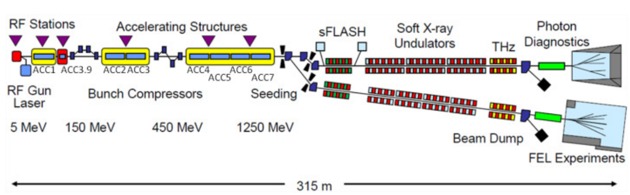

Figure 1: Layout of FLASH accelerator [4].

We measured beam induced HOM at FLASH twice. At the first measurement, some dipole-like modes, the one believed to be beam pipe modes, are found for the 8th TESLA cavity (Cav8) in the 7th cryomodule (ACC7) in September 2013.

In the second experiment, we measured beam induced HOM in the 8th TESLA cavity (Cav8) in the 5th cryomodule (ACC5).

We changed electron beam orbit by using two dipole magnets which are H3DBC3 and V3DBC3 located at upstream of ACC4. Estimated beam positions in the middle of ACC5Cav8 are plotted in Fig.2. These beam positions are estimated from two beam position monitors (BPM) located at upstream and downstream of ACC5. Ignoring beam orbit changes due to Q magnet switched on, and assuming that beam positions are strongly correlated to dipole magnets setting value even though beam passed out of range BPM linearity, beam orbits are calculated with linearly passing between two BPM.

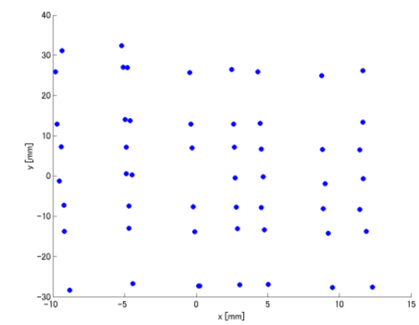

Figure 2: Beam Positions used in beam induced HOM measurements.

A layout of measurement setup is shown in Fig.3. One cavity has two HOM couplers. HOM signal picked up by each HOM coupler was divided twice. We measured the one of signal divided by the first splitter. The other signal was measured by the other measurement group. Two high pass filters (VHF-1500+) which cut off the main RF power whose frequency is 1300 MHz were added before the second splitter were connected. Then HOM signal were divided again for two different frequencies. Branch 1 for TE111-1 consisted of a band pass filter (BPF) from 1605 to 1785 MHz and two amplifiers (ZX60-1614LN-S) whose gain is 14 dB and noise figure is 0.5 dB from 1217 to 1620 MHz. Then branch 2 for beam pipe modes consisted of a BPF from 2100 to 2210 MHz and an amplifier (ZRL-2400LN) whose gain is 28 dB and noise figure is 1.2 dB. Finally, both branches were connected to an oscilloscope (TDS7404). One waveform data taken by the oscilloscope has 200 k points with 5 GSa/s.

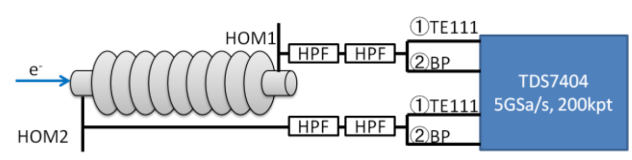

Figure 3: Measurement Setup.

Spectrums of TE111-1 and beam pipe mode (BP) are described as FFT of waveform data in Fig.4-1 and Fig. 5-1.

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The frequency step is about 20 kHz. Two peaks shown in these figures are polarized modes of each mode. We named two peaks as a and b in frequency order. Frequencies of TE111-1a and TE111-1b are 1610.09 MHz and 1610.30 MHz. Frequencies of BP-a and BP-b are 2108.7 MHz and 2116.86 MHz. Amplitudes of these modes normalized by beam charge are plotted with respect to beam positions in Fig. 4-2(a), 4-2(b), 5-2(a) and 5-2(b).

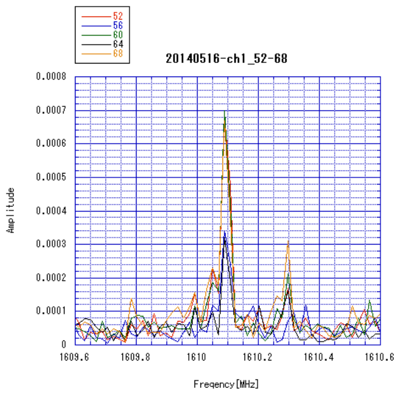


Figure 4-1: Spectrums of TE111-1.

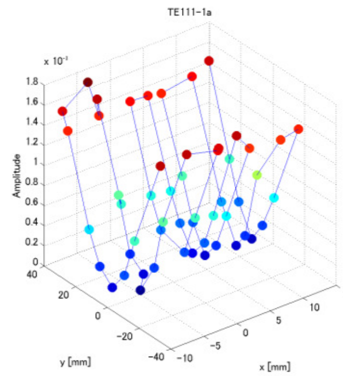


Figure 4-2(a): Amplitude Mapping of TE111-1a.

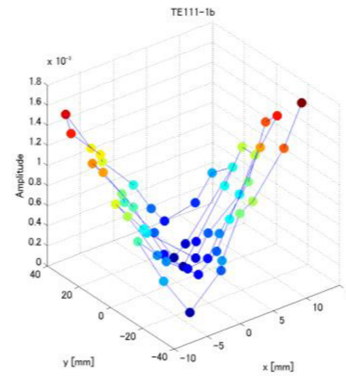


Figure 4-2(b): Amplitude Mapping of TE111-1b.

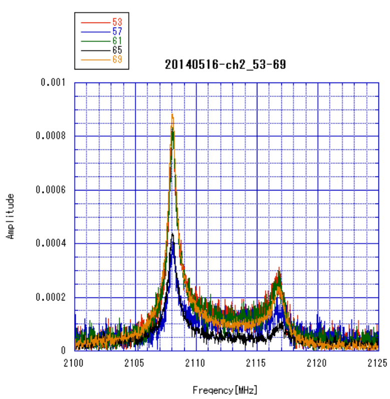


Figure 5-1: Spectrums of Beam Pipe Mode.

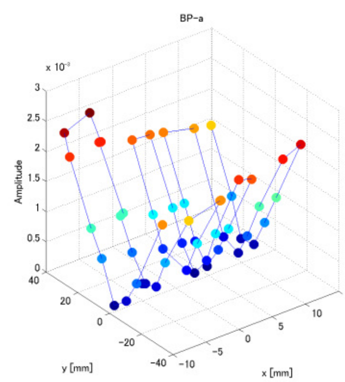


Figure 5-2(a): Amplitude Mapping of BP-a.

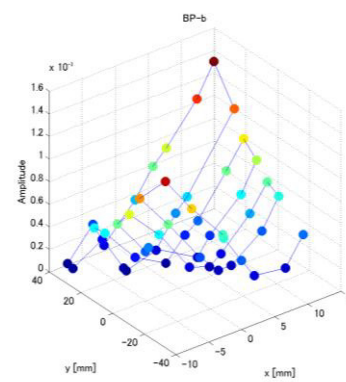
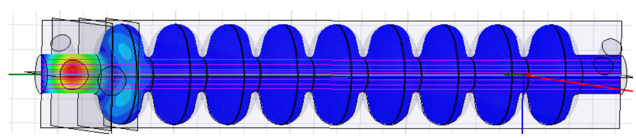


Figure 5-2(b): Amplitude Mapping of BP-b.

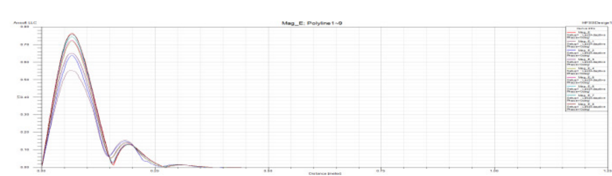
ELECTRICAL CENTER OF BEAM PIPE MODE

Simulation

Simulation of beam pipe mode for a KEK cavity was performed by HFSS 12 [4] eigenmode solver. A mode whose electric field distribution are shown in Fig. 6(a) is appeared at 2194 MHz. Figure 6(b) shows a plot of electrical magnitudes along longitudinal lines which has different offset described as pink lines in Fig. 6(a). Transverse electric field distributions at the highest peak and the second highest peak as shown in Fig. 6(b) are shown in Fig. 6(c) and 6(d). At a part of end cell, mode looks like dipole.



(a) Electric Field Distribution.



(b) Electrical Magnitudes along longitudinal lines.

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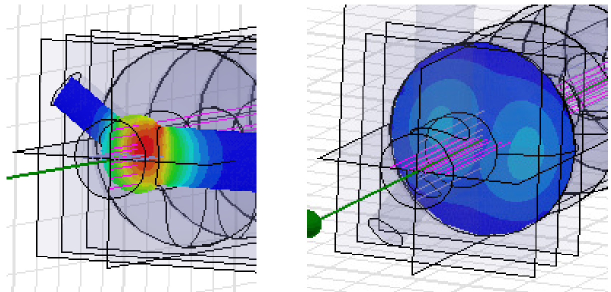

(c) Transverse Electric Field distribution at the highest peak as shown in the upper figure.

(d) Transverse Electric Field distribution at the second highest peak as shown in the upper figure.

Figure 6: Simulation Result of Beam Pipe Mode for a KEK Cavity.

Bead Perturbation Method

When ceramic bead is used as perturbation, frequency change corresponds to a magnitude of electric field. The following figure shows frequency change along longitudinal axis when 6 mm diameter bead was pulled. This electric field distribution whose frequency is 2254 MHz is similar to one calculated by HFSS 12.

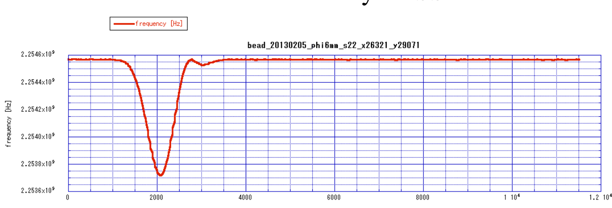

Figure 7: Example of Bead Pull Measurement.

Wire Stretched Method

70 μm-diameter wire is stretched through a KEK cavity on a stage which move in horizontal and vertical direction. BPM calibration pulser is connected the wire and output pulse signals. Then output signals from HOM coupler are connected an amplifier (ZRL-2400LN) and a BPF from 2100 to 2210 MHz and detected by an oscilloscope (DSO9404A). In Figure 8, Red squares (A) indicate 2244 MHz peak amplitude and blue diamonds (B) correspond to 2255 MHz peak amplitude when change wire position with respect to a cavity. These plots are preliminary result. These amplitudes tend to show V-response with respect to wire position offsets. However we cannot say anything still, we expect to measure electrical center position with respect to mechanical center.

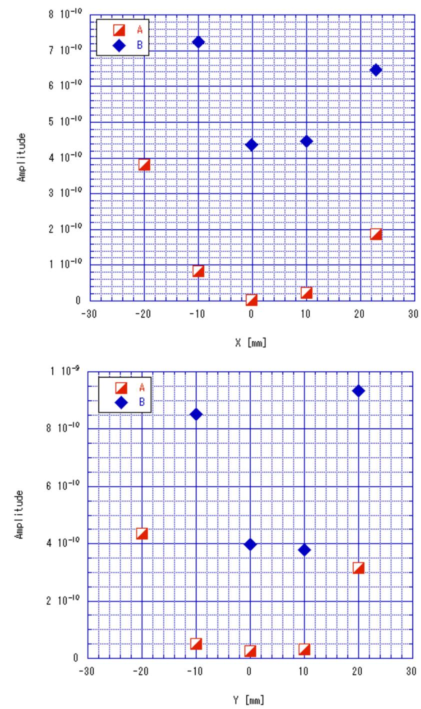

Figure 8: Preliminary result of wire stretched method. The upper plot: wire moved horizontal direction (x). The lower plot: wire moved vertical direction(y).

CONCLUSION

We could detect TE111-1 and beam pipe modes and get amplitude mappings by measurement beam induced HOM at FLASH. Localized mode is found by simulation and bead pull measurement.

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REFERENCES

[1] A. Kuramoto et al., “Beam Induced HOM Analysis in STF”, THP094, these proceedings, SRF2013, Paris, (2013).
[2] A. Kuramoto et al., “Simulations and Measurements of Beam Pipe Modes Excited in 9-cell Superconducting Cavities”, WEPRI029, these proceedings, IPAC’14, Dresden, Germany (2014).
[3] ANSYS HFSS website: http://www.ansys.com/Products/Simulation+Technology/Electronics/Signal+Integrity/ANSYS+HFSS
[4] FLASH website: http://flash.desy.de/