Beam-Based HOM Study in Third Harmonic SC Cavities for Beam Alignment at FLASH

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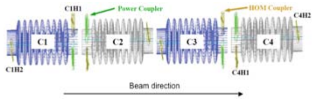
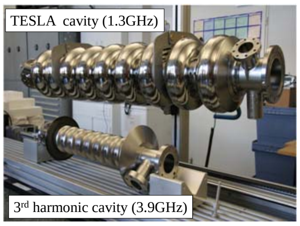
Introduction

ACC39 Module (3.9 GHz)

- Consist 4 third harmonic SC cavities operating at 3.9GHz
- Designed & built by Fermilab
- Installed on FLASH in 2010





Objective

- Higher Order Modes Beam Position Monitor (HOM-BPM)
- Dipole modes dominate transverse wake potentials

$$(Amplitude)_m \sim W_{\perp}^{m} \sim \left(\frac{r}{a}\right)^m$$

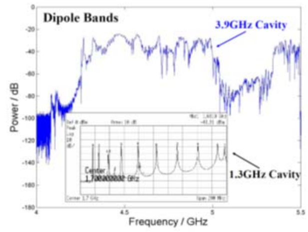
r: beam offset
a: iris radius

m=1, dipole; m=2, quadrupole

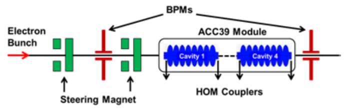
- Use HOMs to remotely align the beam to the electric axis and to measure the beam position

Difficulties

- Considerably larger wakefields (compare to 1.3GHz cavity)
- HOMs are able to propagate through beam pipes attached to cavities
- HOMs shift frequencies in ACC39 module w.r.t. single cavity and hard to identify

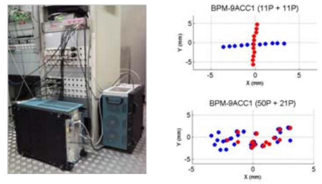


Experimental Setup and Methods



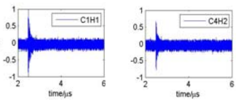
Measurement of beam-excited HOMs

- Move the beam (single bunch) both horizontally, vertically and randomly
- Record signals from all 8 HOM couplers

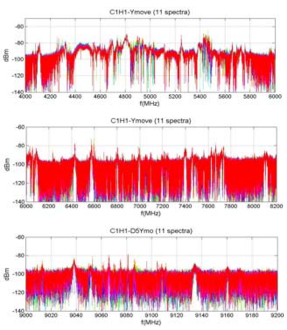


HOM Signals

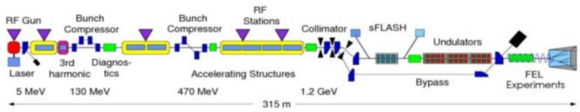
Time-Domain Waveforms

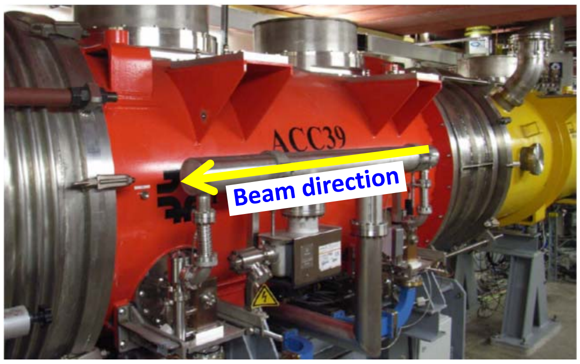


Frequency-Domain Spectra

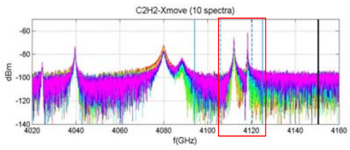


Free-electron LASer in Hamburg (FLASH)

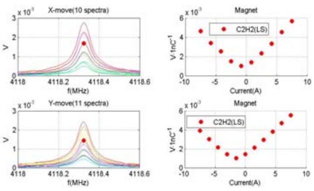




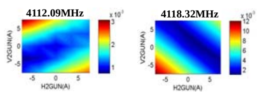
Mode Identification



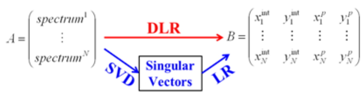
- Lorentzian fit to get amplitude and Q
- Dependence on beam movement



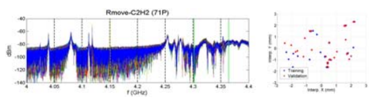
- Power density of dipole modes

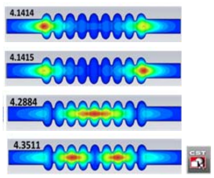


Direct Linear Regression (DLR) vs. Singular Value Decomposition (SVD)



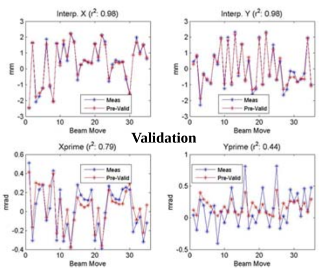
Total Sample = Training (50%) + Validation (50%)





Direct Linear Regression (DLR)

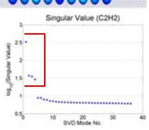
$A \cdot M + B_0 = B$ (size of M is too large)

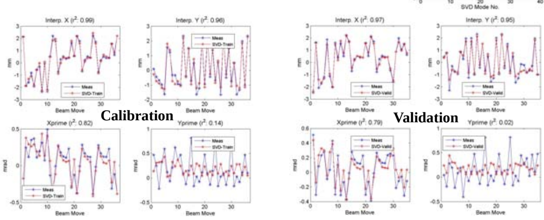


Singular Value Decomposition (SVD)

$A = U \cdot S \cdot V^T \longrightarrow A_S$ (size of A is very small)

$A_S \cdot M_S + B_{0S} = B$ (size of M_S is very small)





Conclusions & Outlook

- HOM dependence on beam movement firstly seen at the third harmonic cavity module
- Various different analysis methods show dipole dependence on beam movement
- Future plans include increasing the coverage in 4D space (x, y, x', y')
- Investigation of suitable modes for diagnostics electronics
- Design electronics for HOM-BPM

Acknowledgements

This research has received funding from European Commission under the FP7 Research Infrastructures grant agreement No.227579.

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