FNAL Microphonics Workshop
Summary and Conclusions
Presented by L. Doolittle, for J.P. Holzbauer and the rest of the Workshop Participants
10/15/2015
Workshop Description

- Workshop Goal: “Stimulate discussion of microphonics and vibration issues including experience from previous machines and discussion of requirements for future machines.”
- 1.5 Day workshop at FNAL with 16 talks on day one, half day of round table discussion the second day (Oct 8-9, 2015).
- About 25 attendees in person, about 20 remote connections.
- Labs Represented: FNAL (AD, TD), LBL, SLAC, ANL-APS, FRIB, Cornell, JLab, RRCAT
- [indico.fnal.gov/event/micro1](indico.fnal.gov/event/micro1)
- References and supporting documents have been trickling in to the workshop indico page in response to questions/comments.
Topics Discussed

• Vibrational Driving Terms
  - Environmental, mechanical sources, measurement & mitigation

• Mechanical Design, Optimization, and Validation
  - Cryomodule/cavity/tuner characterization, design, prototype, production
  - Experience from CEBAF, FRIB, Cornell, FNAL

• LLRF Control Systems/Active Resonance Control
  - State of the art LLRF and active resonance stabilization techniques
  - Plans for future development/collaboration

• Organizational Challenges of Resonance Control
  - How do we communicate vibrational issues to all organizational levels?
  - How do we document the lessons learned and actually learn from them?
  - What resources are needed to effectively implement resonance control across a large, dispersed project like LCLS-II?
The Challenges of LCLS-II

- While much of the technology used for LCLS-II is derived from XFEL/ILC experience
- One of the most challenging aspect of this adaptation is the smaller cavity bandwidth, and commensurate increased sensitivity to detuning
- In this aspect, successful XFEL operation is not an assurance of LCLS-II success, there is no operational machine meeting these requirements!
- The developed experience with narrow bandwidth cavities worldwide gives cautious optimism that the mandated LCLS-II cavity frequency stability can be achieved
- Many of the individual techniques required for LCLS-II have been demonstrated, and now have to be engineered into a large-scale system
- Even the best active control won’t be adequate if the rest of the machine sub-systems don’t provide a quiet environment
Vibration Environment

- Achieving a tolerable displacement environment (what active control is asked to compensate) is a fundamentally multidisciplinary problem
- Examples of this were presented from all involved
Cornell ERL Injector – Cryo Dead End

- An additional, unexpected heat load on a cooldown valve lead to a repetitive bubble formation and collapse, causing large pressure transients
- Took significant time and effort to diagnose, mitigate, and ultimately fix
• Anomalous trips in CEBAF injector module traced to helium pressure fluctuations
• Module located at end helium transfer line, pressure rise in line meant chimney limit was exceeded
• Required extensive effort to diagnose and mitigate
• Presented as serious detuning transients/RF trip
• Known prior issue WITHIN JLab
Many examples of identification and mitigation of specific external driving terms were presented.

Many terms were external to the module and correctable to some level, but required diagnosis time and effort.

Other examples presented include water pumps/flow, construction vibration.
System Design – Simulation and Prototyping

- Consensus that prototyping and testing were essential to performance
- Simulation a crucial element of the process, but not enough alone
- Simulations should be used to both predict issues and diagnose

- Cornell Main Linac cavity prototype df/dP disagreed with simulations
- Data was used to improve simulations by including more realistic weld preps

M. Liepe - Cornell
C100 Cryomodule Fix

- Design allows for 25 Hz Peak Detuning
- Actual peak detuning (21 Hz) was higher than expected in first cryomodules
- A detailed vibration study was initiating which led to the following design change.
  
  - A minor change to the tuner pivot plate substantially improved the microphonics for the CEBAF C100 Cryomodules.
  
- While both designs meet the overall system requirements the improved design has a larger RF power margin

<table>
<thead>
<tr>
<th>Microphonic Detuning*</th>
<th>C100-1</th>
<th>C100-4</th>
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</thead>
<tbody>
<tr>
<td>RMS (Hz)</td>
<td>2.985</td>
<td>1.524</td>
</tr>
<tr>
<td>6σ(Hz)</td>
<td>17.91</td>
<td>9.14</td>
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Prototype Cryomodule Testing

- Examples were given from FRIB, Cornell, JLab, FNAL about the extensive learning process required when working on prototype cryomodules
- XFEL designs and experience provide a serious leg-up for most cryomodule technologies used for LCLS-II
- The additional challenges faced by LCLS-II resonance control means that prototype module testing time and resources will be critical to success, for both passive and active resonance control
- JLab is developing an extensive microphonics/vibrational test plan for their prototype cryomodule
- While testing time and resources are at a premium, support for this type of testing and collaboration among the LCLS-II partners is considered essential among the resonance control community
Curt Baffes at FNAL has started a program for PIP-II in an attempt to systematically address environmental noise sources.

This document centers around gathering of existing knowledge and experience, dissemination/education, and enforcement of implementation.

Specifically recommended are regular facility walkthroughs and in-situ measurements to identify changes.

- Best Practices Document
  - What hardware/techniques are known/proven?
  - Common examples of vibration sources.
  - Guidelines for passive isolation of vibration-causing equipment
  - Guidelines for passive measures in beamline structural design

http://pip2-docdb.fnal.gov/cgi-bin/ShowDocument?docid=30
Active Resonance Control

- There is general agreement that the program of active control algorithms and techniques development is moving forward well
- Achievements to date give cautious optimism for LCLS-II performance
- Progress on all fronts limited by access to realistic testing platforms
Summary

- Workshop was well attended and very productive
- Consensus that resonance control is a uniquely challenging problem in that unexpected vibration from nearby sources can completely disrupt machine performance
- Project support of a broad-based approach to microphonics control is crucial to monitoring/enforcing vibrational issues across the machine
- Cryomodule and conventional facilities design must apply lessons learned from previous machines, following ‘Best Practices’ (codified if possible)
- The project would benefit from developing meaningful, testable, defensible, and constructive vibrational specifications. They are unlikely to ever be complete and understandable enough to replace ‘Best Practices’
Thank you

Thanks to all participants of the Workshop for their valuable contributions on short notice