High Beta and Low Beta 650 MHz PIP-II cavity testing at Fermilab 650STC

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Introduction

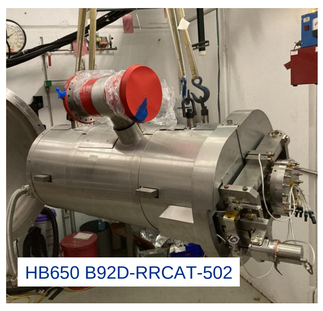
The Fermilab 650 STC (Spoke resonator Test Cave) is used as a horizontal test facility for the PIP-II 650 MHz Low Beta(LB) and high beta (HB) superconducting cavities. The cavities are 5-cell elliptical doublet type with betas of 0.61 and 0.9. Cavity detuning measurement calibration, microphonics studies, piezo tuner performance, field control and resonance control performance parameters are some of the system measurements completed.

Overview of Tested Cavities

- HB650, beta=0.9, **B9A-AES-001**
- January-March 2020
- STC commissioning for 650 MHz operations
- Prototype coupler/tuner validation/testing
- Prototype cavity characterization


HB650 B9A-AES-010

- HB650, beta=0.92, **B92D-RRCAT-502**
- October-November 2021
- Prototype coupler/tuner validation/testing
- Prototype cavity characterization, qualification for prototype HB650 cryomodule assembly


HB650 B92D-RRCAT-502

- LB650, beta=0.61, **B61-EZ-001**
- June-September 2022
- Preproduction coupler/tuner testing
- Prototype cavity characterization


LB650 B61-EZ-001

Test Stand


Upgraded STC


Bare HB650 Cavity


LB650 Cavity on ANL EP stand

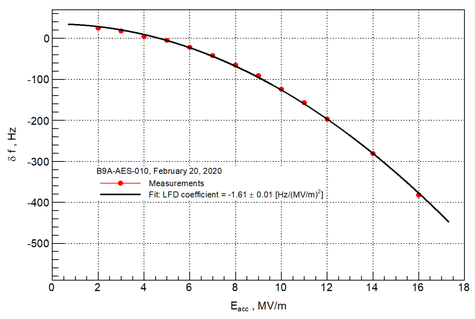
Test Sequence

- Cooldown from room temperature to 2K
- Tuner tests at 2K
- Coupler conditioning at 2K with cavity off-resonance
- Cavity on-resonance conditioning (multipactor, field emission)
- Cavity characterization (max E_{acc}, Q_0, df/dp, Lorentz force detuning)
- LLRF testing/Resonance control development
- Coupler/tuner measurements
- Warmup to Room Temperature
- Coupler conditioning w/o HV bias

Cavity Measurements

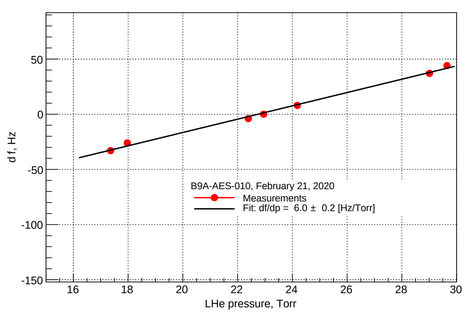
Lorentz Force Detuning(LFD)

Cavity	LFD coefficient, Hz/(MV/m)**2
B9A-AES-010	1.6
B92D-RRCAT-502	1.0
B61-EZ-001	2.4



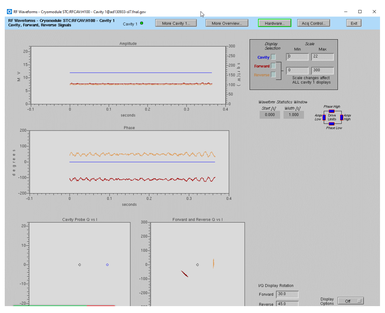
Pressure sensitivity

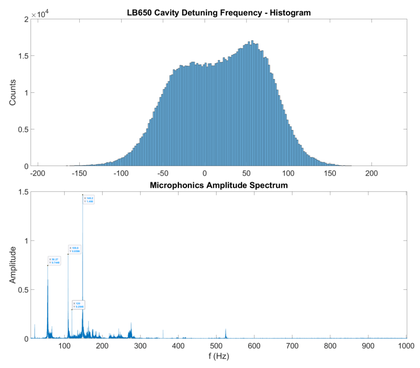
Cavity	df/dp, Hz/Torr
B9A-AES-010	6.0
B92D-RRCAT-502	15
B61-EZ-001	27



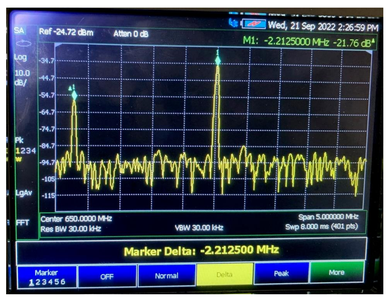
LLRF System Testing on LB650 Cavity

LB650 GDR Mode at 17 MV/m

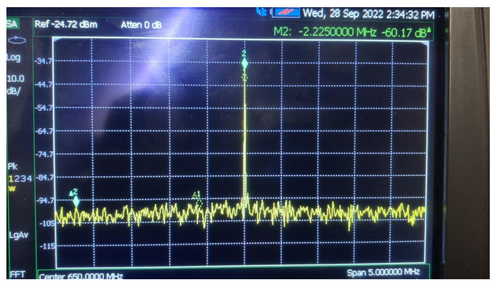




4/5π and 3/5π Passband Modes

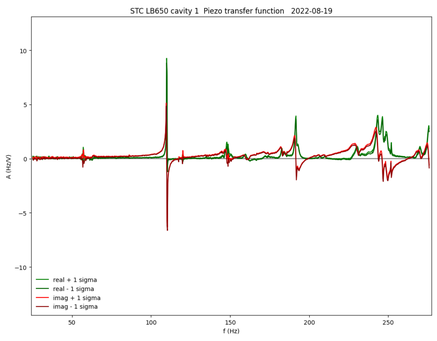


Suppression with Notch Filters

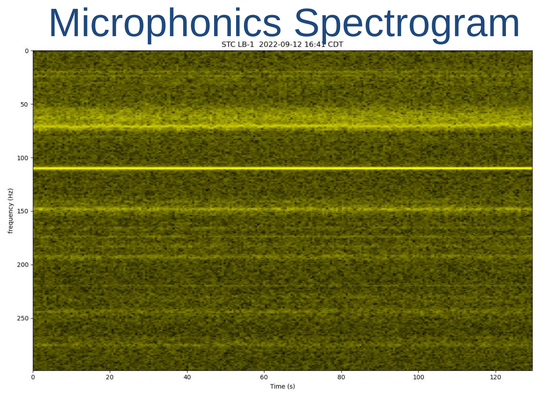


Microphonics Measurements

Piezo Transfer Function



Microphonics Spectrogram



Summary

- Two high beta and one low beta cavity have been tested so far at STC. The LB cavity with a high LFD coefficient was challenging to run in GDR mode with an IQ feedback controller. Amplitude and phase control feedback using LCLS-II controller made it possible to reach the full gradient in GDR mode.
- System development is a collaboration between the Fermilab and LBNL LLRF teams.
- Hardware is also a mix of components developed for PIP-II as well as LCLS-II projects.

PIP-II

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