Electro-Mechanical Properties of Spoke-Loaded Superconducting Cavities

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Collaborators

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**Cavity RF Power Requirements**

- In many applications superconducting cavity RF frequency variations are on the level of or greater than the loaded-cavity bandwidth.

- Mechanical deformations drive RF eigenfrequency variations.

- Reactive RF power required to control the cavity RF phase is given by [J.R. Delayen, Ph.D Thesis, Cal-Tech, 1978]:

\[ \delta \omega \cdot U \]

- Mechanical Properties of Triple-Spoke-Loaded Cavities
  - Pulsed operation ↔ Lorentz detuning of a \( \beta = 0.5 \) triple-spoke-loaded cavity
  - Continuous-Wave operation ↔ Microphonic-noise of a \( \beta = 0.5 \) triple-spoke-loaded cavity
ANL $\beta = 0.5$ Triple-Spoke Cavity Lorentz-Detuning

$$f(t) = \int LTF(\Omega) \cdot E_{acc}^2(\Omega) \cdot e^{-i \cdot \Omega \cdot t} d\Omega$$

$$k_L = -11.5 \text{ Hz}/(\text{MV/m})^2$$
ANL $\beta = 0.5$ Triple-Spoke Cavity Pulsed Response

\[ f(t) = \int LTF(\Omega) \cdot E_{acc}^2(\Omega) \cdot e^{-i\Omega t} \, d\Omega \]
ANL $\beta = 0.5$ Triple-Spoke Cavity Predicted Pulsed Response

$$f(t) = \int LTF(\Omega) \cdot E_{acc}^2(\Omega) \cdot e^{-i\Omega t} d\Omega$$
ANL $\beta = 0.5$ Triple-Spoke Cavity Lorentz Detuning

- The Lorentz transfer function characterizes the Lorentz force driven interaction between a resonant cavity’s electromagnetic field and mechanical eigenmodes.
- The Lorentz transfer function is a powerful tool for studying and analyzing Lorentz detuning in superconducting cavities.
- The Lorentz transfer function accurately characterized the pulsed response of the $\beta = 0.5$ triple-spoke-loaded cavity.
- The $\beta = 0.5$ triple-spoke-loaded cavity was optimized for continuous-wave operation.
I am finished talking about Lorentz detuning.

Now I am going to talk about microphonic-noise.

Microphonic-noise for superconducting spoke-loaded cavities is mainly low-frequency non-resonant noise, 4 K liquid helium bath boiling.
ANL $\beta = 0.5$ Triple-Spoke Cavity Microphonic Noise

Reference Oscillator Phase Noise

$P_{in} = 100$ W

$\sigma_{rms} = 0.44$ Hz
ANL $\beta = 0.5$ Triple-Spoke Cavity Microphonic Noise

$P_{in} = 100$ W
Conclusions

- The bandwidth of microphonic-noise for superconducting spoke-loaded cavities is very small.

- The rms RF frequency deviation of the $\beta = 0.5$ triple-spoke-loaded cavity is 0.44 Hz and barely above the reference oscillator phase-noise.

- Mechanical fast tuners have been developed to damp the remaining microphonic-noise. See poster WEP67 and Michael Kelly’s talk(WE302; today 11:20-11:40AM).