Microphonics in CW TESLA cavities
and their compensation with fast tuners
Motivation for microphonics detuning control

Superconducting CW Cavity operational aspects:
(from LLRF control simulations)

Phase stability ~ 0.02° achievable without further means?

A. Neumann, 13th International Workshop on RF Superconductivity, Beijing 2007
How bad is the real world? \rightarrow \text{Measure microphonics}

What are the mechanics of my system? \rightarrow 

\text{Tuner-cavity characterization, Transfer function}

Combine information of detuning and transfer function \rightarrow 

\text{Implement compensation scheme}
The test facility and measurement setup

HoBiCaT-Test facility for up to two TESLA units

- $T_{\text{LHe}} = 1.8$ Kelvin
- Bandwidths \~20-40 Hz
- Measurement accuracy by mixer and RF source: 0.2 Hz at 1.3 GHz

Open loop detuning detection by comparing phase between RF source and measured field

Low Level RF setup
Possible detuning sources

Field strength variations:
Dynamic Lorentz forces

Helium pressure fluctuations
20-50 Hz/mbar
↔ level variations?

2.5 mm Niobium walls

“Random“-broadband machinery noise

Deterministic, narrow bandwidth sources:
Vacuum pumps, water cooling pumps

nm-movements $\rightarrow \Delta f \sim \text{Hz}$

Possible system response of cavity-tank-tuner system predicted by FEM simulations, see e.g.
Devanz et al. EPAC 2002
Bisoffi, BESSY-report, 2003

Piezo-to-RF Transfer function
Characteristics of microphonics

Typical example:

100 hour measurement:
RMS detuning usually low (1-2 Hz rms)
But peak events up to 17 standard deviations

Integrated microphonics ($Hz_{rms}$)
1.4 Hz rms
Excited mechanical eigenmode

σ_f = 1-5 Hz rms

Spectrum time invariant?

Time-frequency analysis of detuning data
Analysis of the detuning

Microphonics spectrum visualized with WAVELETS

- Eigenmode contribution: Strong variation with time
- Cannot be controlled by simple feedforward
- Adaptive/Learning system needed
Countermeasure: Fast tuning systems

Characteristics

Saclay I

Saclay II

Replace metal fixture by piezo element holder frame

Tested Saclay I and Saclay II tuning system

See Poster WEP 058 by O. Kugeler
The piezo-to-RF detuning transfer function

Deformation $\Delta l$

Voltage $V(t)$

Cavity deformation transfers to detuning $\Delta f$

Compare Amplitude and Phase of excitation and RF response

Nature of microphonics and transfer function
set boundary conditions for controller design
Two-folded approach: **Low frequency feedback** and **adaptive feedforward**

- Control LHe caused detuning $< 1 \text{ Hz } f_{\text{mod}}$
- Control fast osc., mech. resonances

\[
\tilde{W}(n) = \tilde{W}(n-1) + \frac{\mu}{\text{VAR}(X(n))} \cdot e(n) \tilde{X}(n)
\]

\[
Y(n) = W^T(n-1) \cdot \tilde{X}(n)
\]
Detuning compensation at a nine-cell TESLA cavity

Factor 7.6 of compensation

Improved open loop phase stability: $13.2 \rightarrow 2.0^\circ$

Limit by piezo-tuner resolution
• Microphonics: Pressure fluctuations of LHe bath, mechanical eigenmodes

• Need for a fast tuning system to save RF power and improve CW field stability

• Very stable cryogenic system important, 20-30 μbar

• Compensation by slow feedback and adaptive feedforward algorithm

• Reduction between a factor of two up to seven

• Open loop phase stability up to 1° for f_{1/2}~10-20 Hz

To do (at least):

• Show long-term stable, reliable operation, combine with LLRF control

• Improve tuner resolution
Thanks to:

**CEA-Saclay:** Pierre Bosland, Guillaume Devanz, Eric Jacques, Michel Luong

**BESSY:** Wolfgang Anders, Jens Knobloch, Oliver Kugeler, Michael Schuster, Sascha Klauke, Dirk Pflückhahn, Stefan Rotterdam

**DESY:** Kai Jentsch, Clemens Albrecht, Lutz Lilje

Work funded by the European Commission
in the Sixth Framework Program, contract no. 011935 EUROFEL

Further questions? Meet me at WEP56