Vibration Measurement

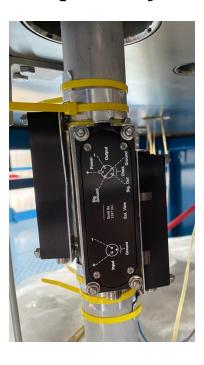
Tom Krokotsch

Setup

3 x (Accelerometers +



Amplifier)



> Readout



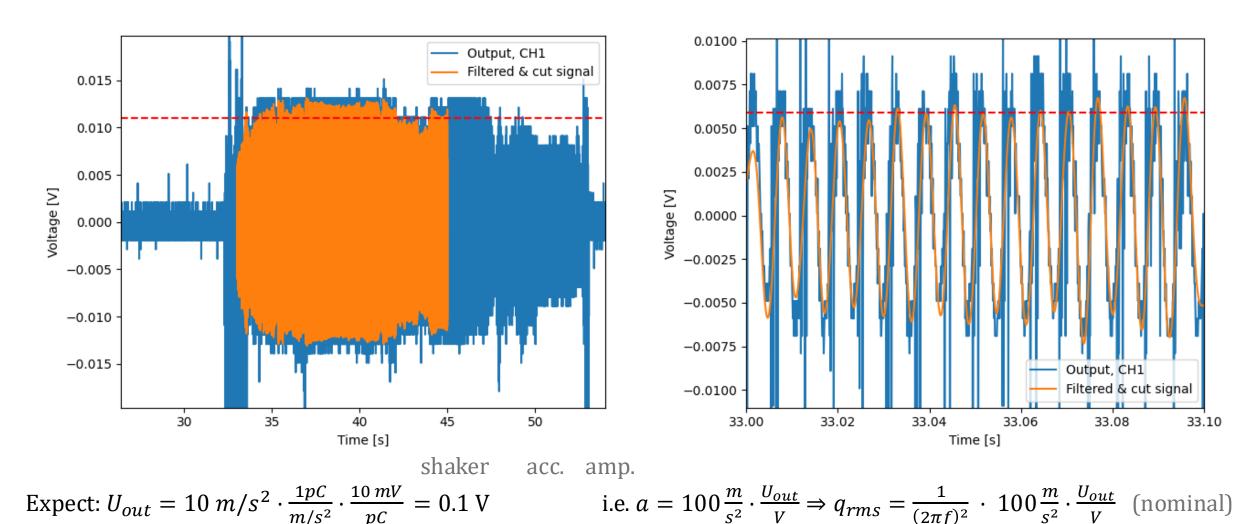






Sensors at 26 K for cavity at 2K (Producer specifies > 77 K)

Calibration

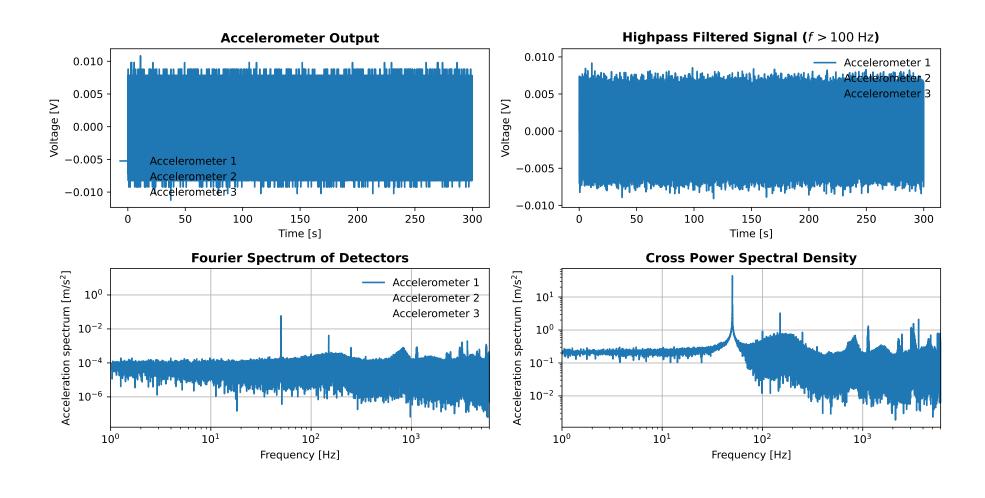


i.e. $a = 1000 \frac{m}{s^2} \cdot \frac{U_{out}}{V}$

(calibrated)

Find: $U_{out} \approx 0.01 \text{ V}$

Spectrum at 2K (Sensors still work)



Inferred average displacement

$$q_{rms\ (full)}^2 = \lim_{T \to \infty} \frac{1}{T} \int dt |q_T(t)|^2 = \int df \ S_q(f) \qquad q_{rms\ (BW)}^2 \approx \frac{f_m}{Q_m} S_q(f_m)$$
with $S_q(f) = \int d\tau \left\langle R_{ij}(\tau) \right\rangle_{i \neq j} e^{-i2\pi f \tau}, \quad i, j = 1, 2, 3$
and $R_{ij}(\tau) = \lim_{T \to \infty} \frac{1}{T} \int dt \ q_i(t - \tau) \ q_j(t)^*$

Note that $S_q(f_c) \propto T$ for coherent signals at f_c . However, q_{rms} does not depend on T.

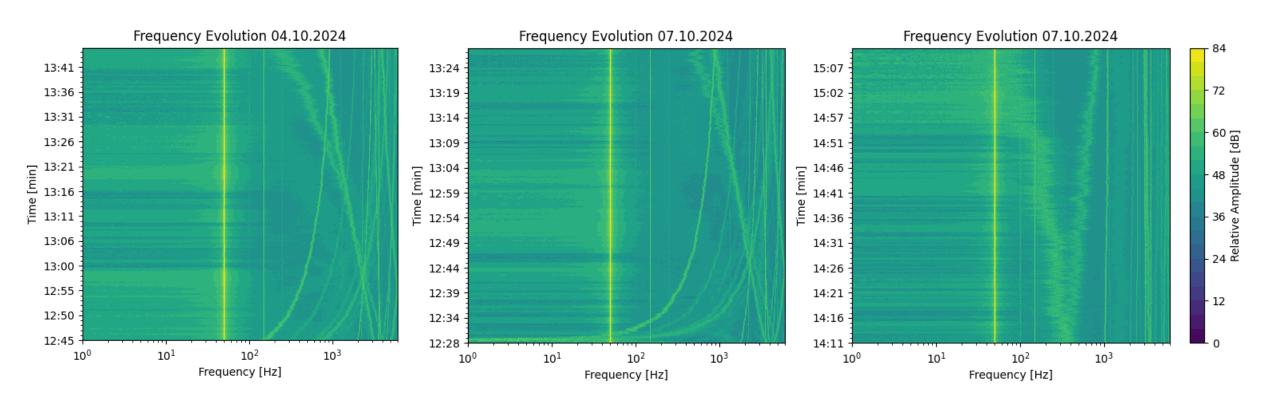
E.g. for a constant background $S_q(f) = S_q(f_0)$ and a mechanical bandwidth $\Delta \omega_m = 10^{-2} \frac{\omega_m / 10^4 \text{Hz}}{Q_m / 10^6}$ we find $q_{rms} = 10^{-10} \text{m} \frac{S_q(f_0)^{1/2}}{10^{-9} \text{m Hz}^{-1/2}} \cdot \frac{\Delta \omega_m^{1/2}}{10^{-1} \text{Hz}^{1/2}}$

Inferred average displacement

(Cavity@2K, During Testing, nominal sensitivity) **Accelerometer Output Highpass Filtered Signal** (f > 100 Hz) 0.010 Accelerometer 1 0.010 Accelerometer 1 Accelerometer 2 Accelerometer 2 Accelerometer 3 Accelerometer 3 0.005 0.005 Voltage [V] Voltage [V] 0.000 0.000 -0.005-0.005-0.010-0.01050 100 150 200 250 300 200 250 300 50 100 150 Time [s] Time [s] **Fourier Spectrum of Detectors Cross Power Spectral Density** Displacement spectrum q(f) [m/Hz] Accelerometer 1 10^{-2} Accelerometer 2 $\sqrt{S_q(f)}$ [m/Hz^{1/2}] Accelerometer 3 10^{-8} 10^{-11} 10^{-14} 10^{0} 10^{1} 10^{2} 10^{3} 10^{0} 10^{1} 10^{2} 10^{3} Frequency [Hz] Frequency [Hz] $q_{rms\,(BW)} \approx 10^{-1} \sqrt{\frac{f_m/10^3}{O_m/10^5}} S_q(f_m) \approx 0.6 \cdot 10^{-10}$ (calibrated sensitivity)

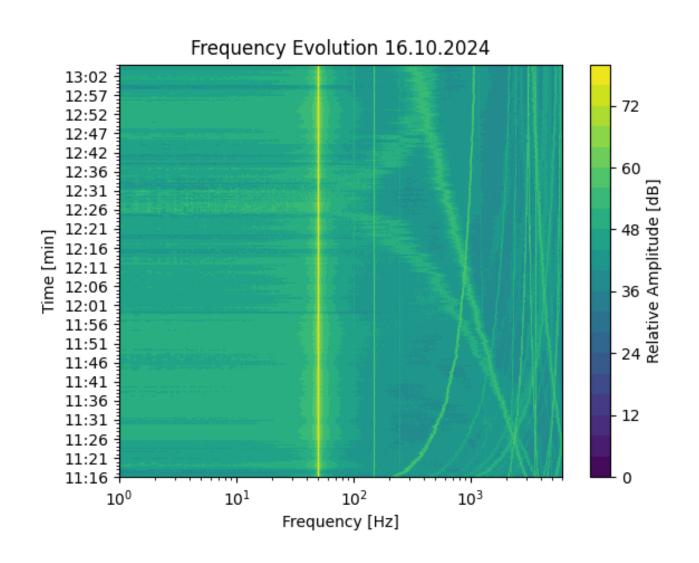
→ Similar values for other datasets

Measurement at 4K (cavity resting)

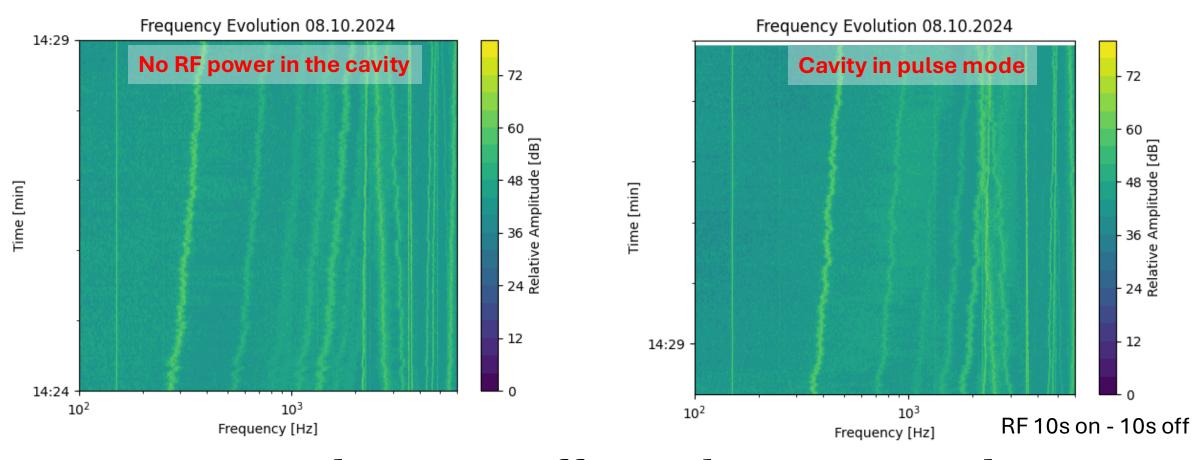


Noise sources seem to chirp

Same Measurement, slightly longer



Measurement at 2K during testing

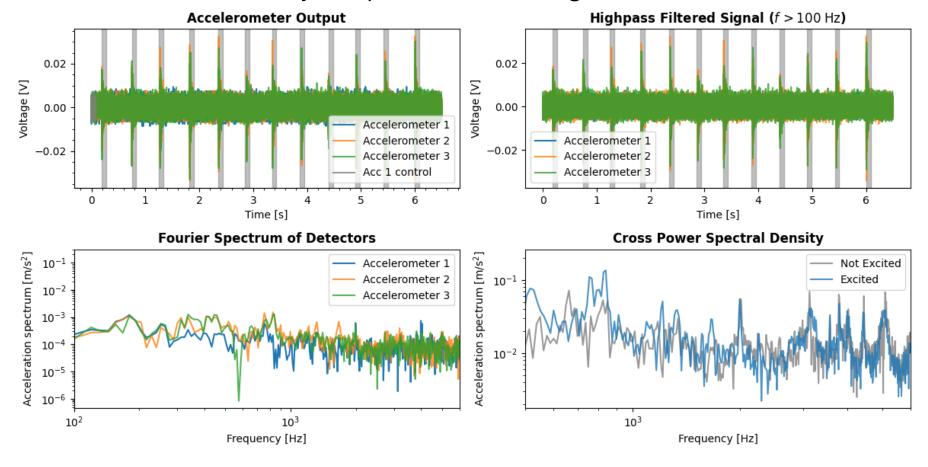


RF power does not affect vibrations **at** the measurement point

Excitation of Insert Modes (With Hammer)

Idea: • Hammer is broadband \rightarrow excites mainly resonances

Machinery/Pumps could drive strong vibrations off-resonance



- ⇒ Small differences, but dominant peaks are still the same
- ⇒ The machinery appears to cause mostly broadband vibrations