Crackle Noise: Finding an Upper Limit

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LIGO-G1300862-v1

What is Crackle Noise?

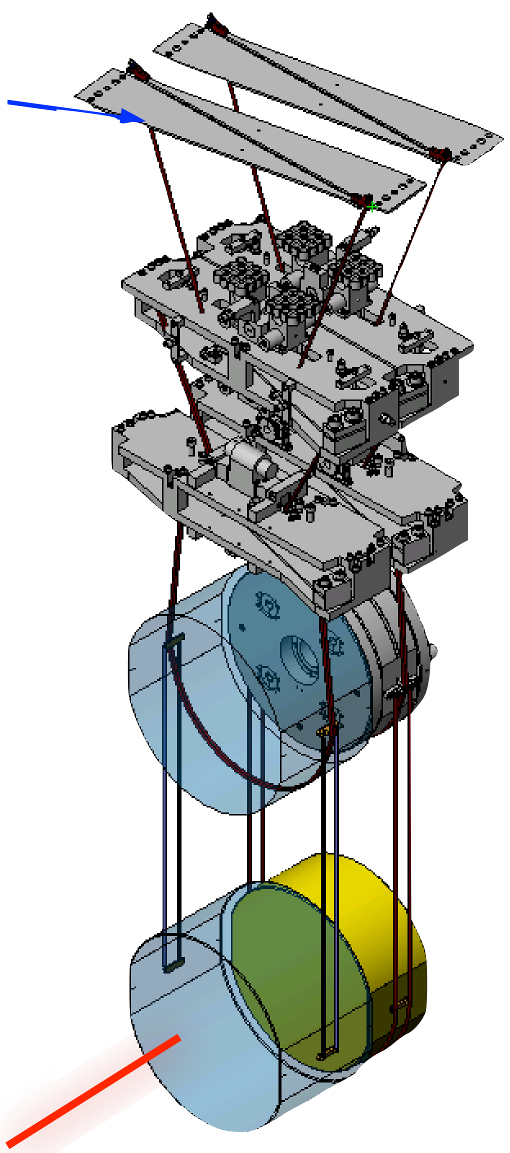
- Technical Definition: Crackle occurs when a system responds to slowly changing external conditions through discrete, impulsive events spanning a broad range of sizes.

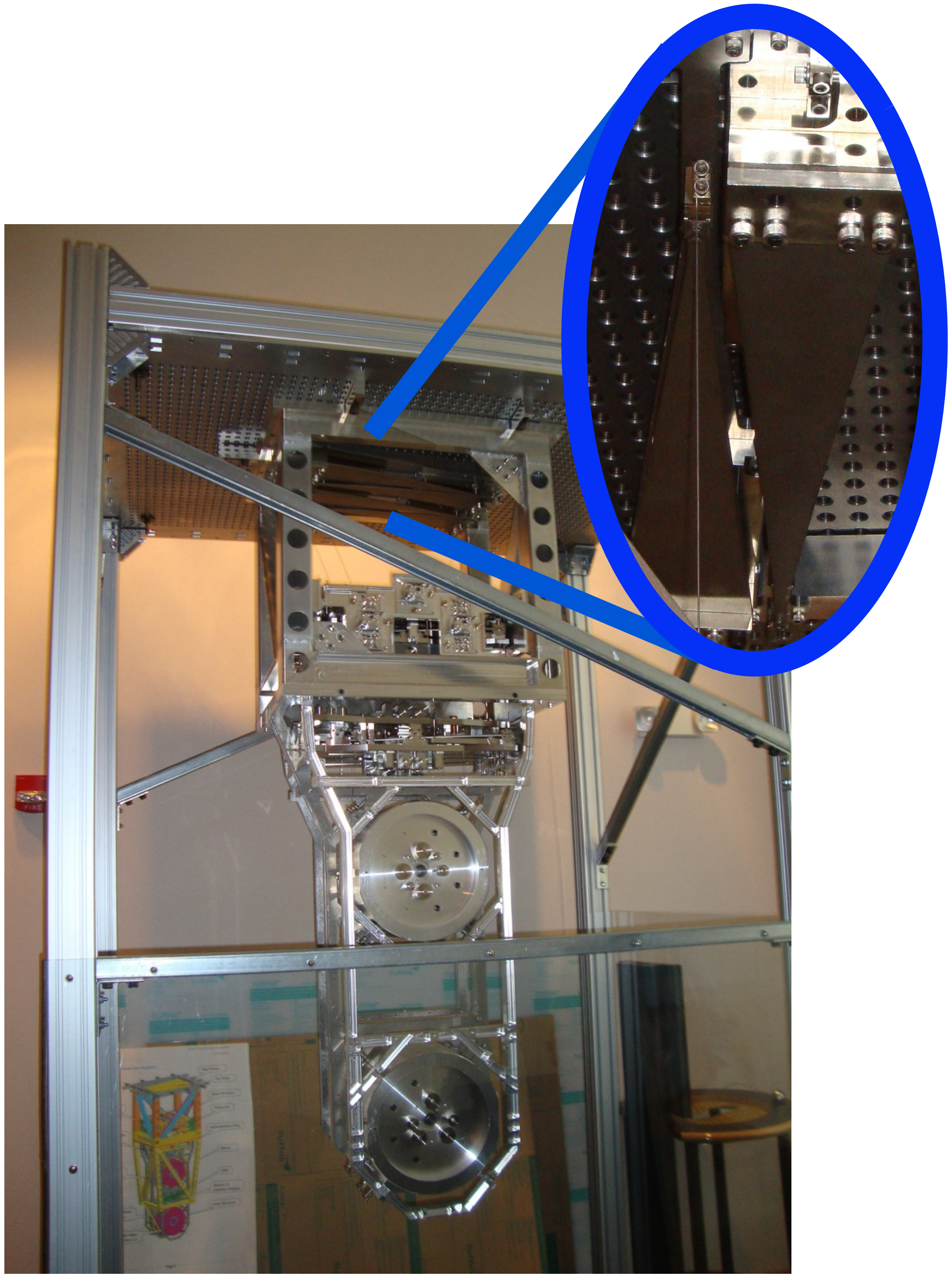
Why Do We Care?

- Tectonic activity can cause crackle in LIGO suspensions
- Could cause noise in the sensitivity band
- But, how bad is it?

LIGO's Blade Springs

- We will test blade springs for crackle first

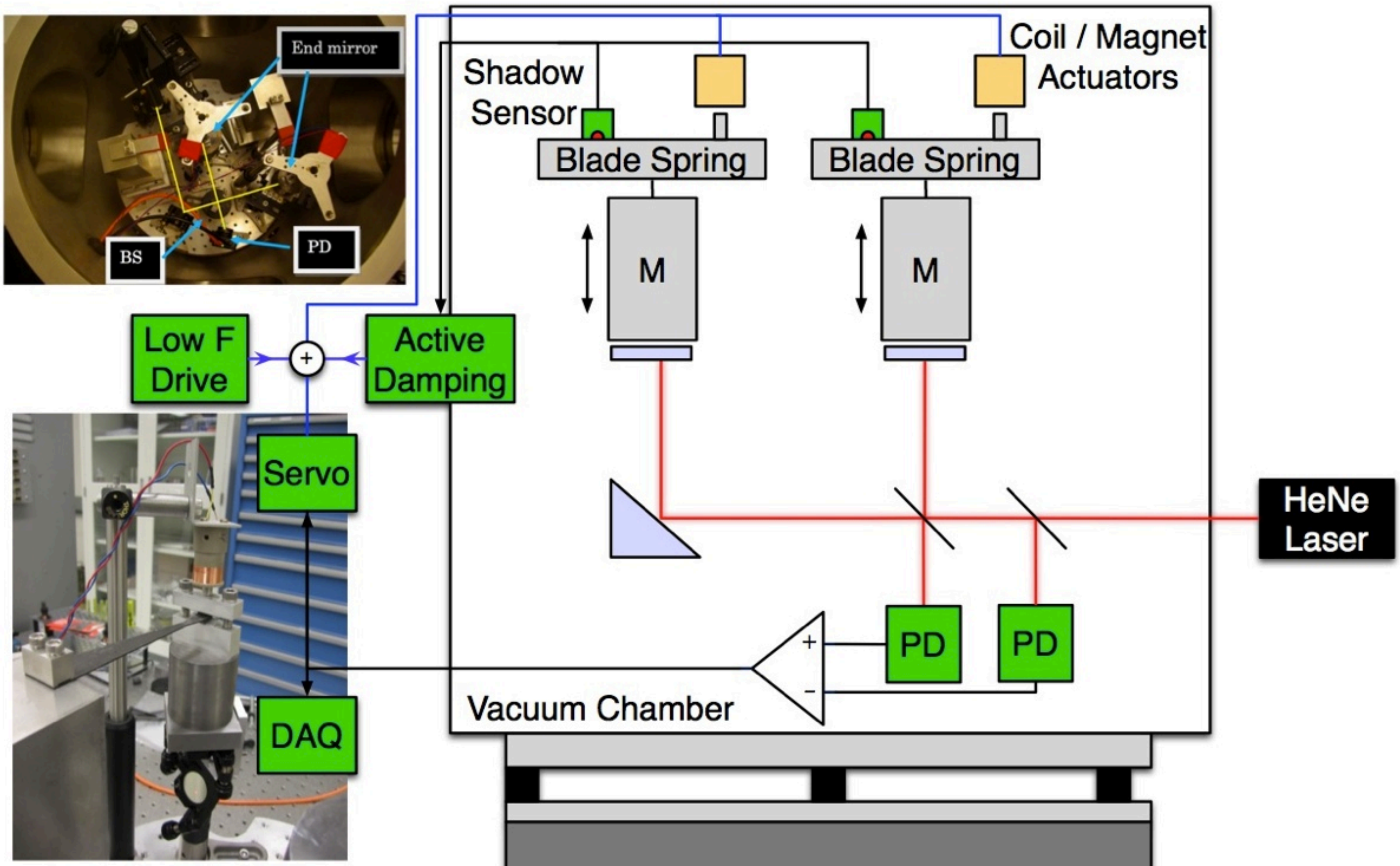




Experiment Overview

- Hang test masses from 2 blade springs
- Make these the end mirrors of a Michelson
- Lock differential displacement of masses
- Drive the system at a low frequency
- Output of Michelson will measure differential displacement caused by crackle

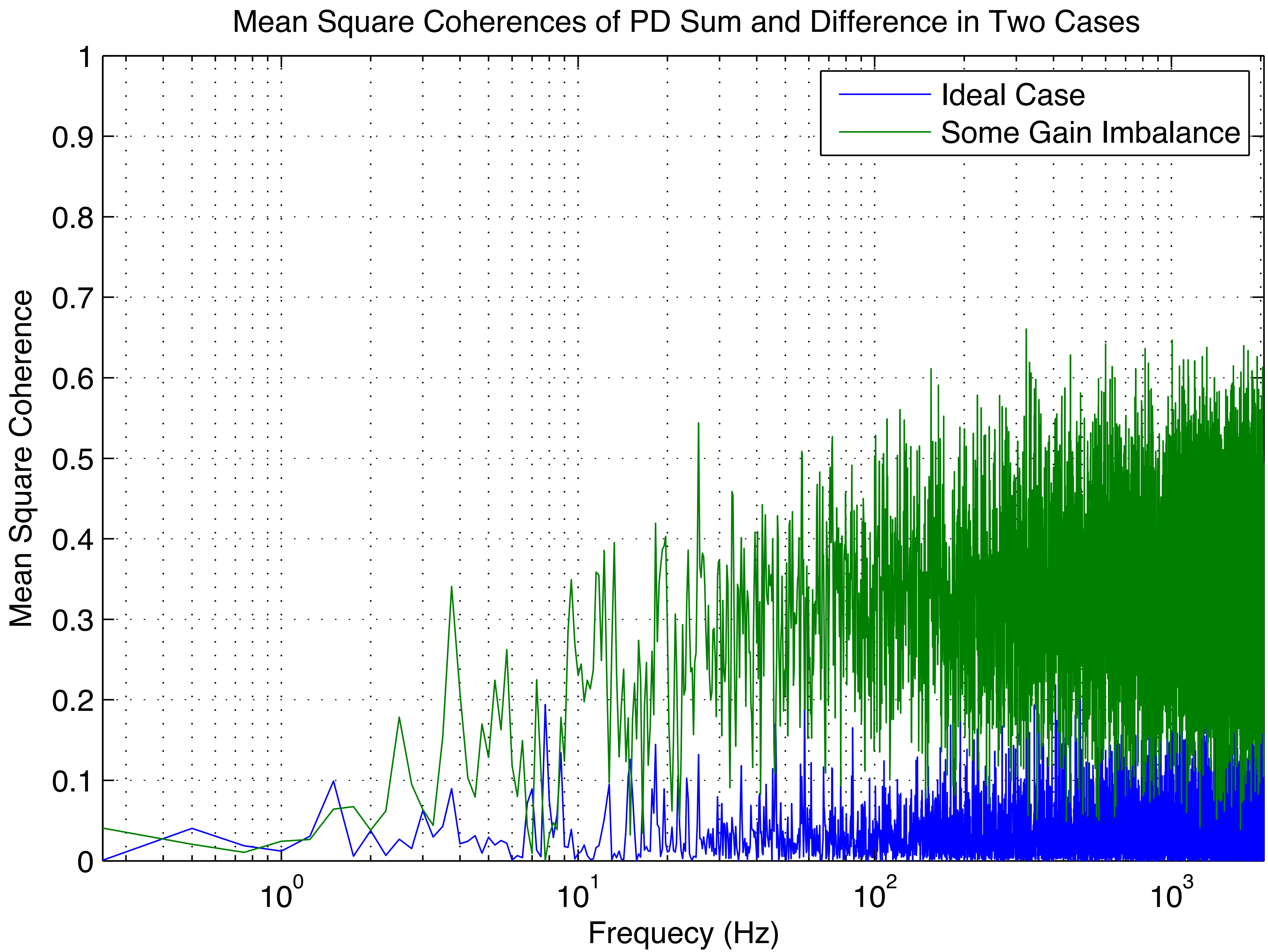
Experiment Overview



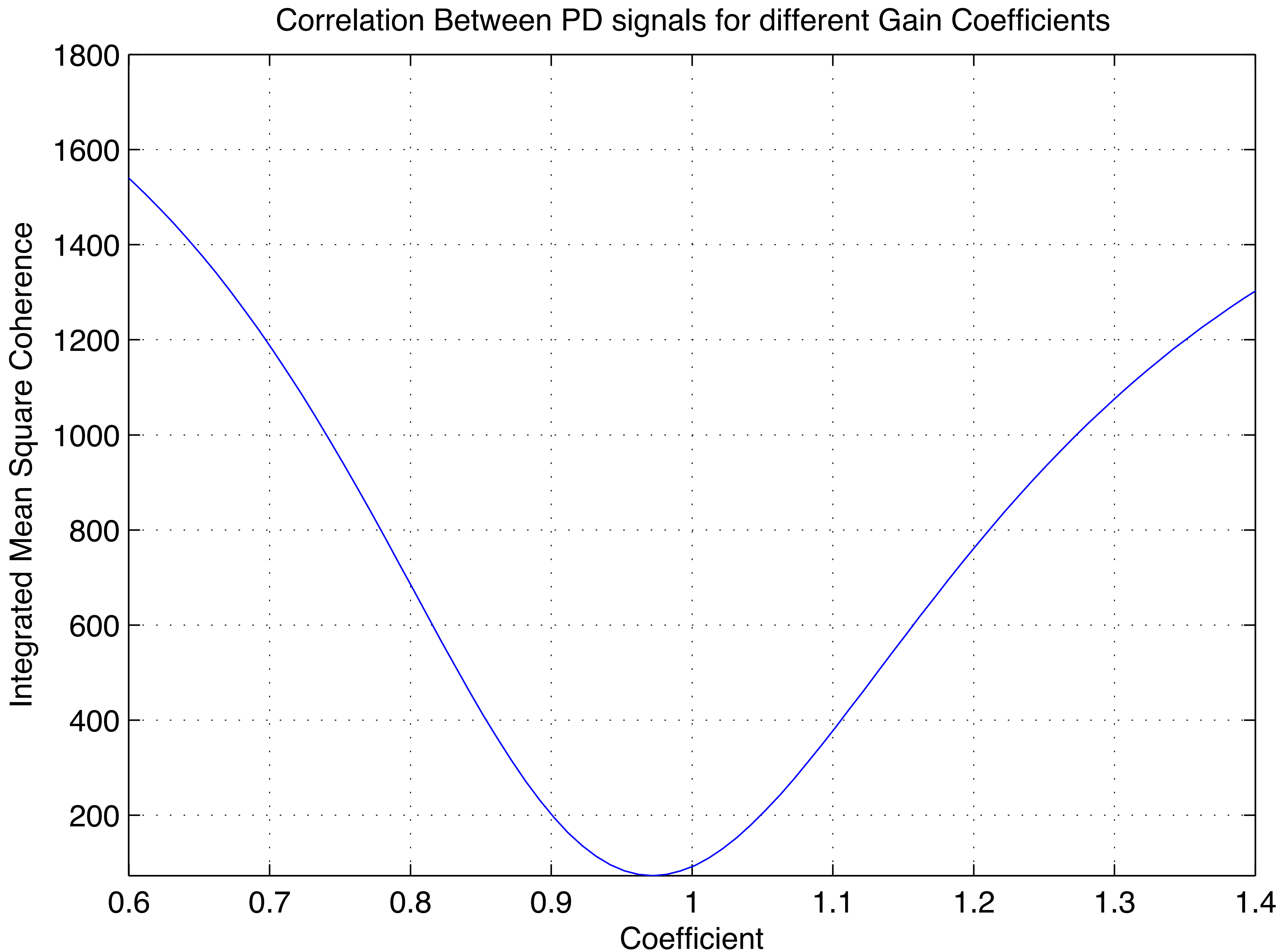
Minimizing Other Noise

- Adjusting Photo Detector Output Gain
  - Unbalanced gains reduces sensitivity
    - $V_a = G_a(dx + IntensityNoise + ShotNoise_a)$
    - $V_b = G_b(-dx + IntensityNoise + ShotNoise_b)$
  - We must minimize coherence between sum and difference of signals

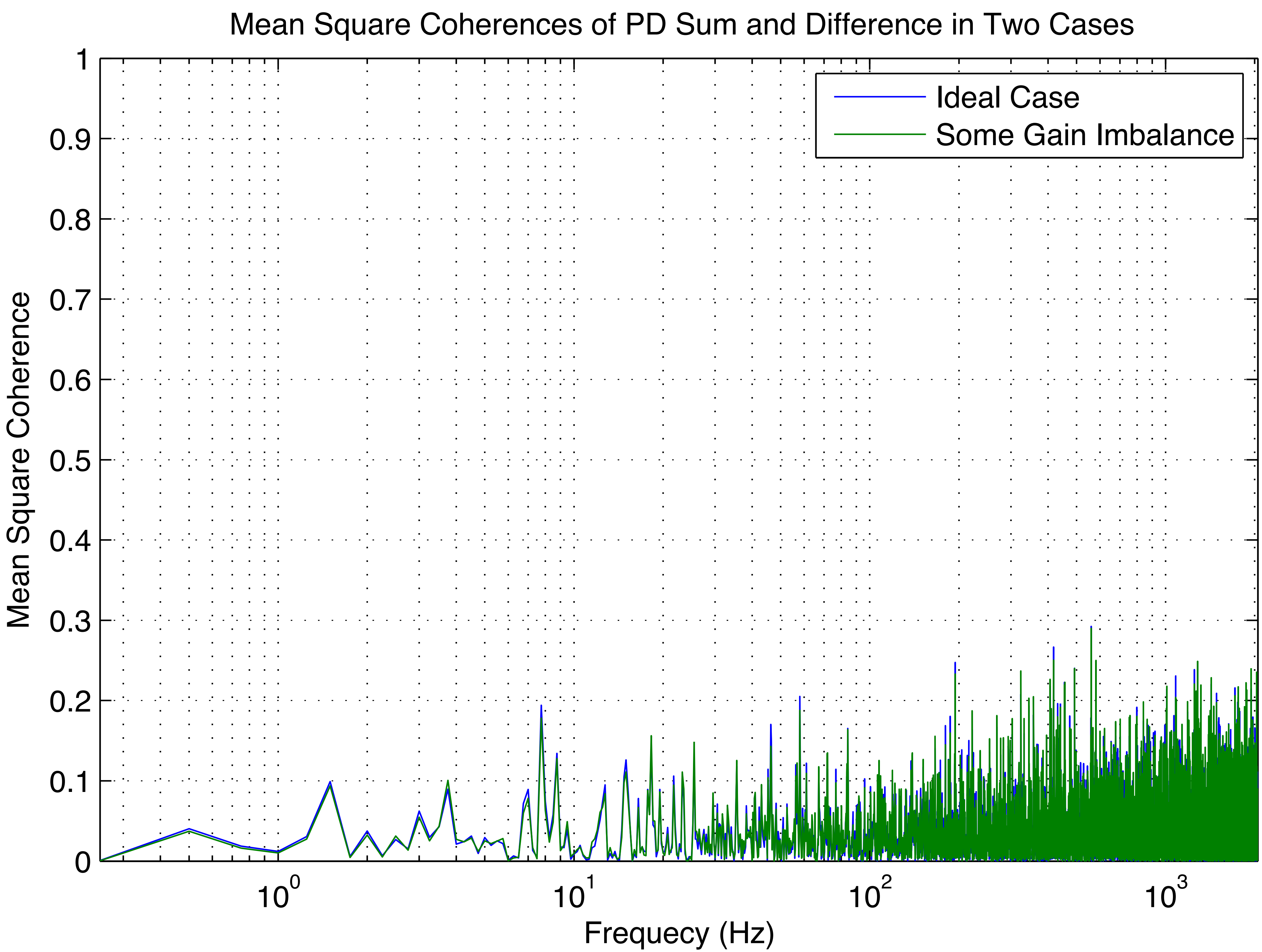
Minimizing Other Noise



Minimizing Other Noise

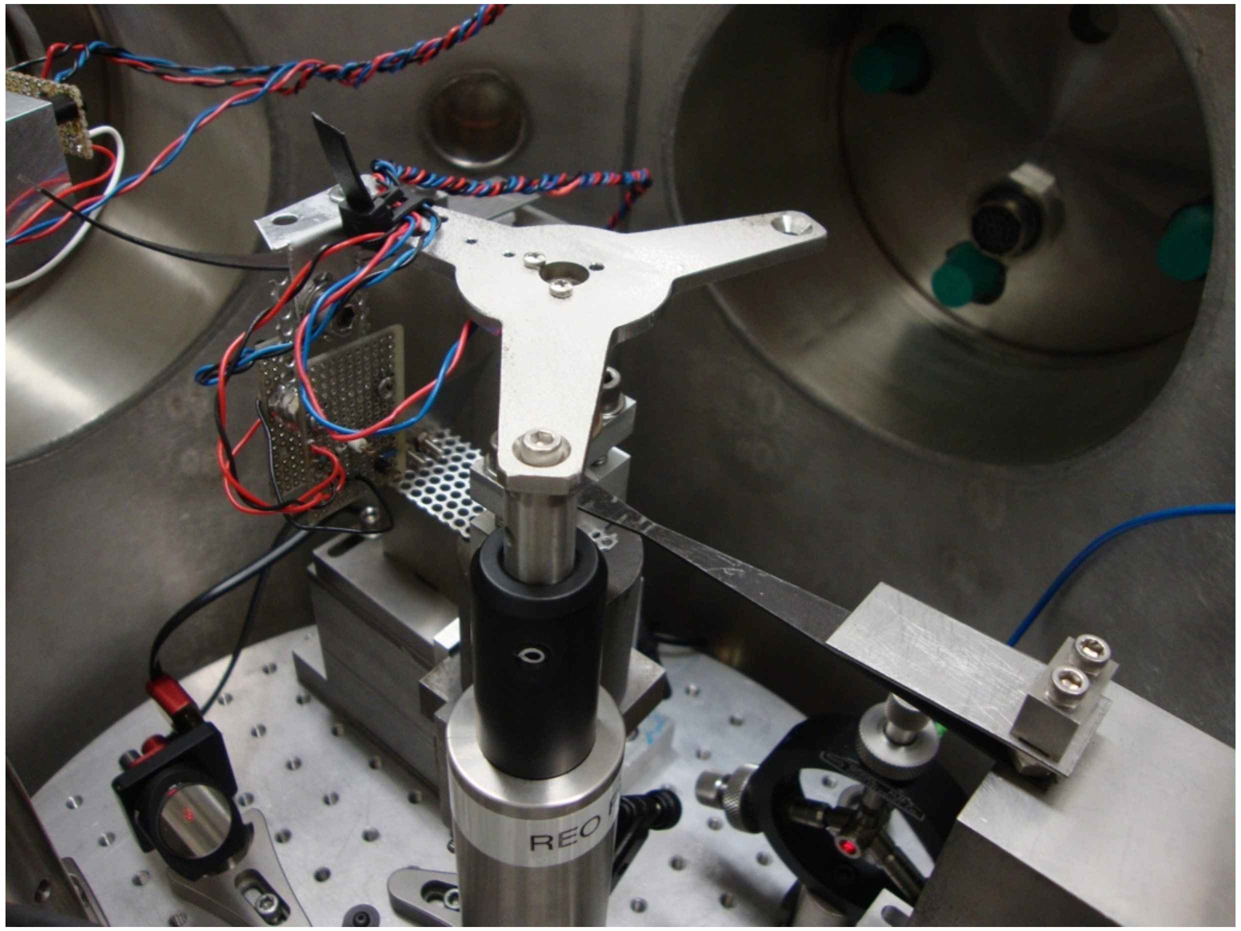


Minimizing Other Noise

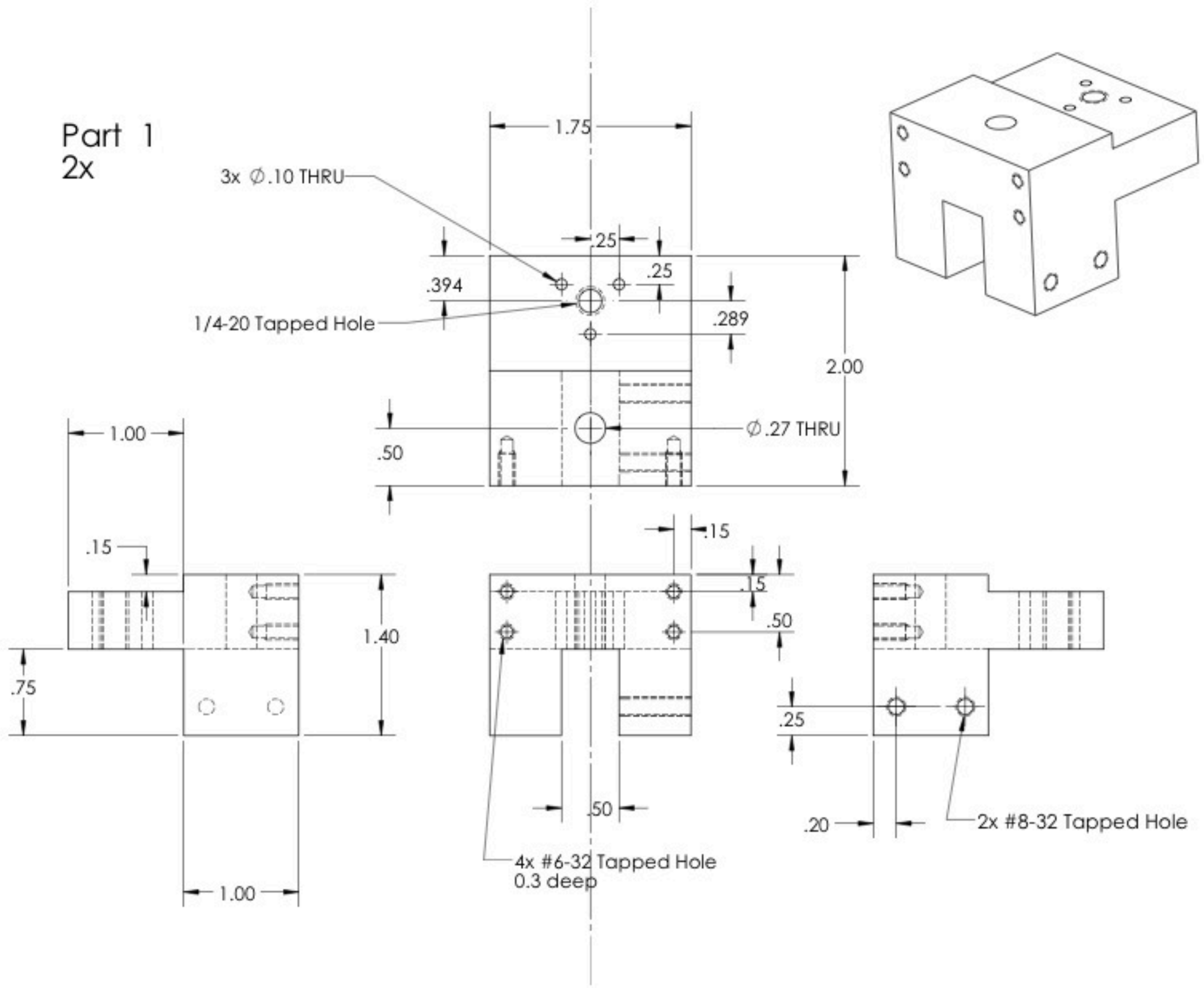


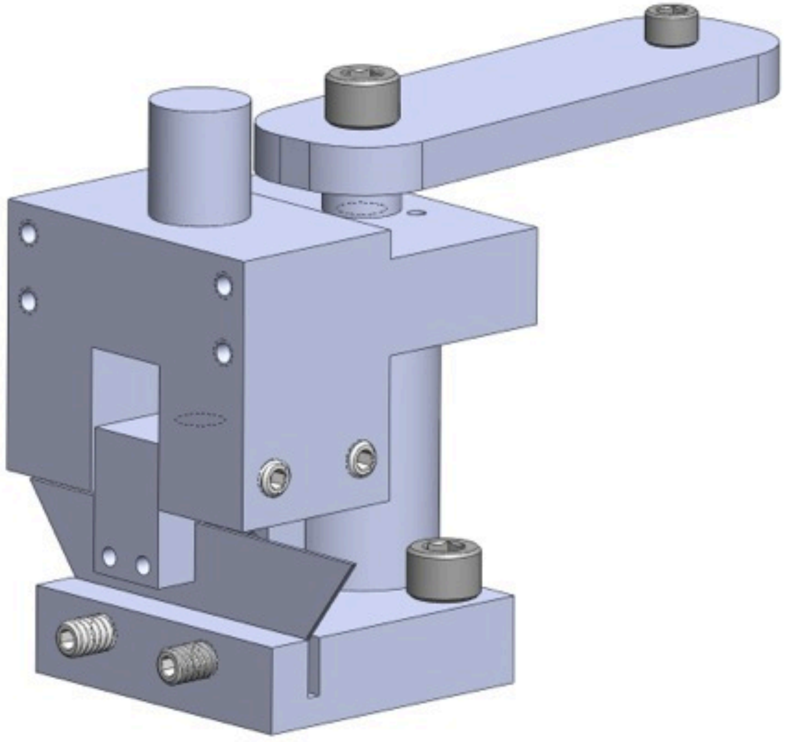
Minimizing Other Noise

- Designing Better Shadow Sensor Mounts
  - Flimsy mounts could cause vibrations
  - We needed a more adjustable assembly

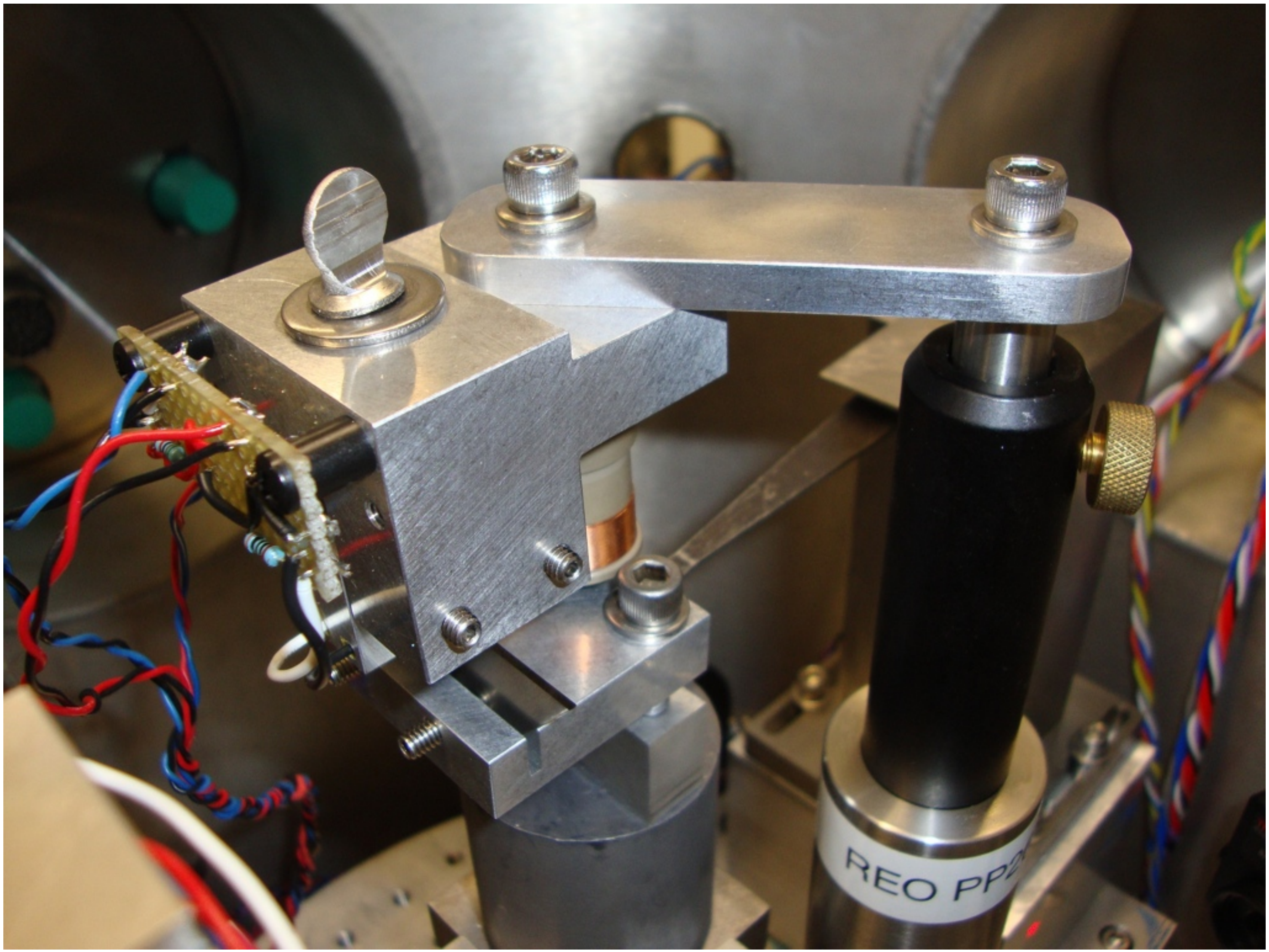


Minimizing Other Noise



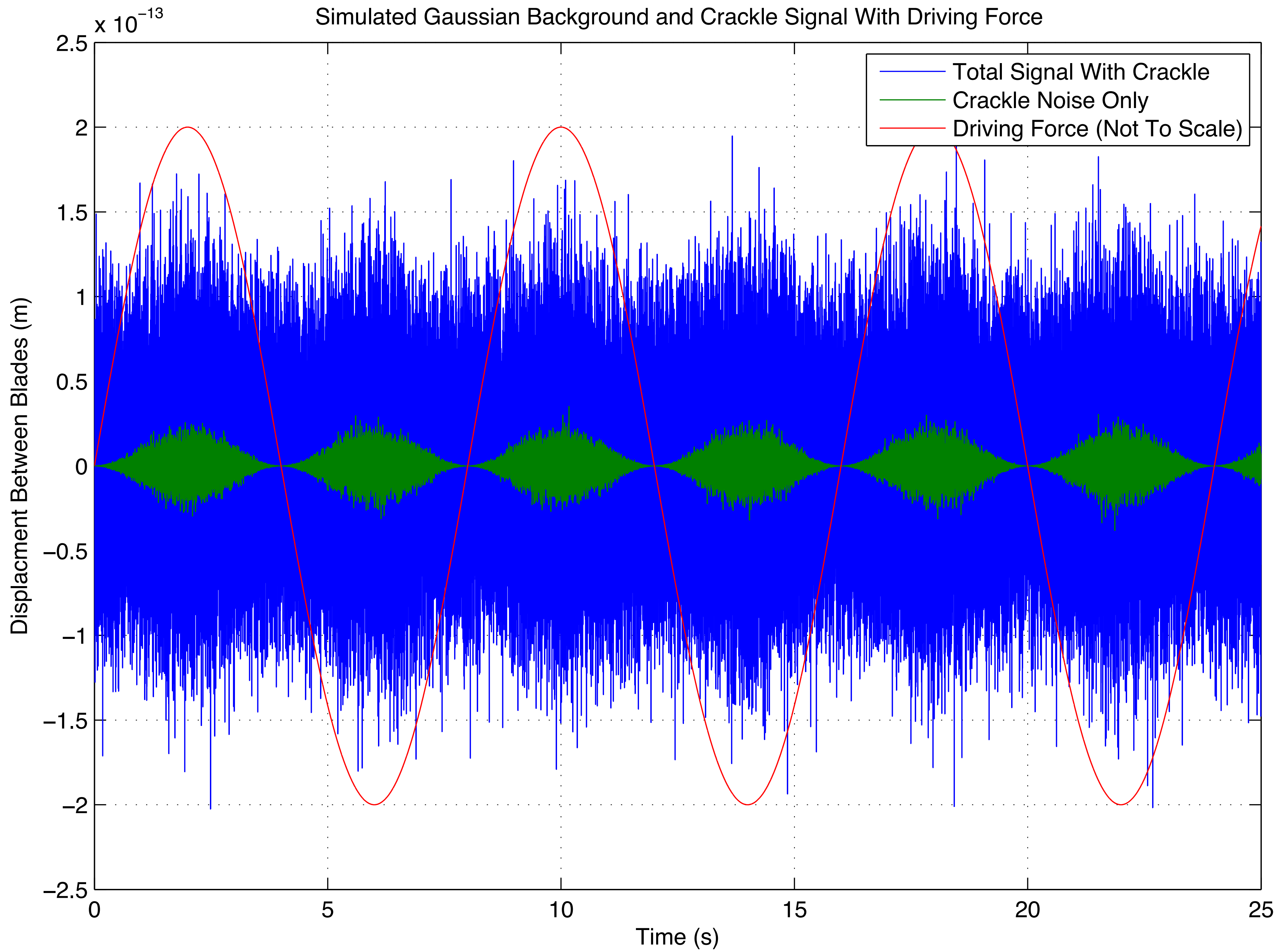


Minimizing Other Noise



Analysis

- Crackle is proportional to the driving force



Analysis

- To demodulate, we use two quantities:

$$Q = \cos(2\omega_d t) \cdot signal^2$$

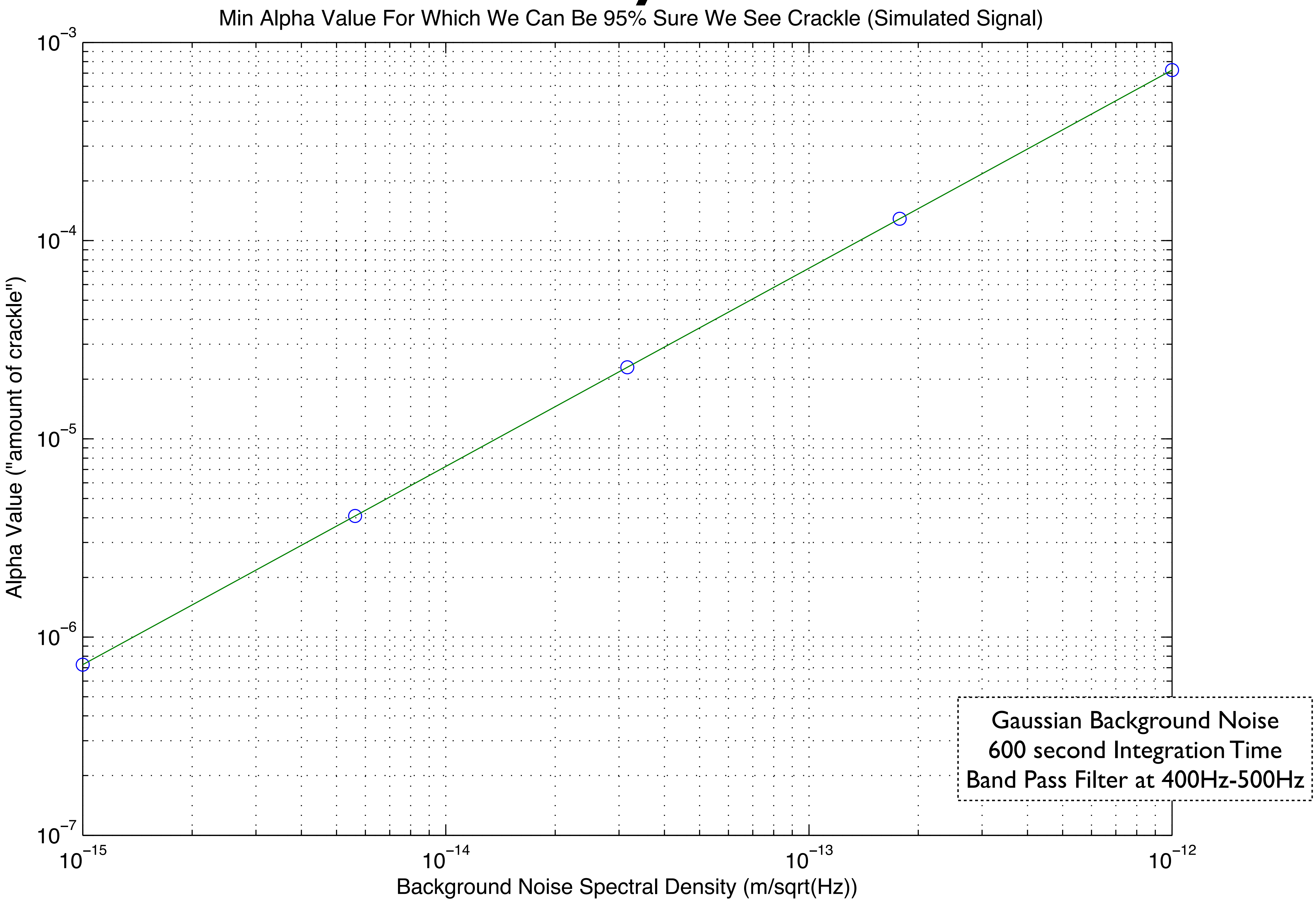
$$I = \sin(2\omega_d t) \cdot signal^2$$

- Q exhibits a DC offset in the presence of crackle because the *signal*^{2} has this term:

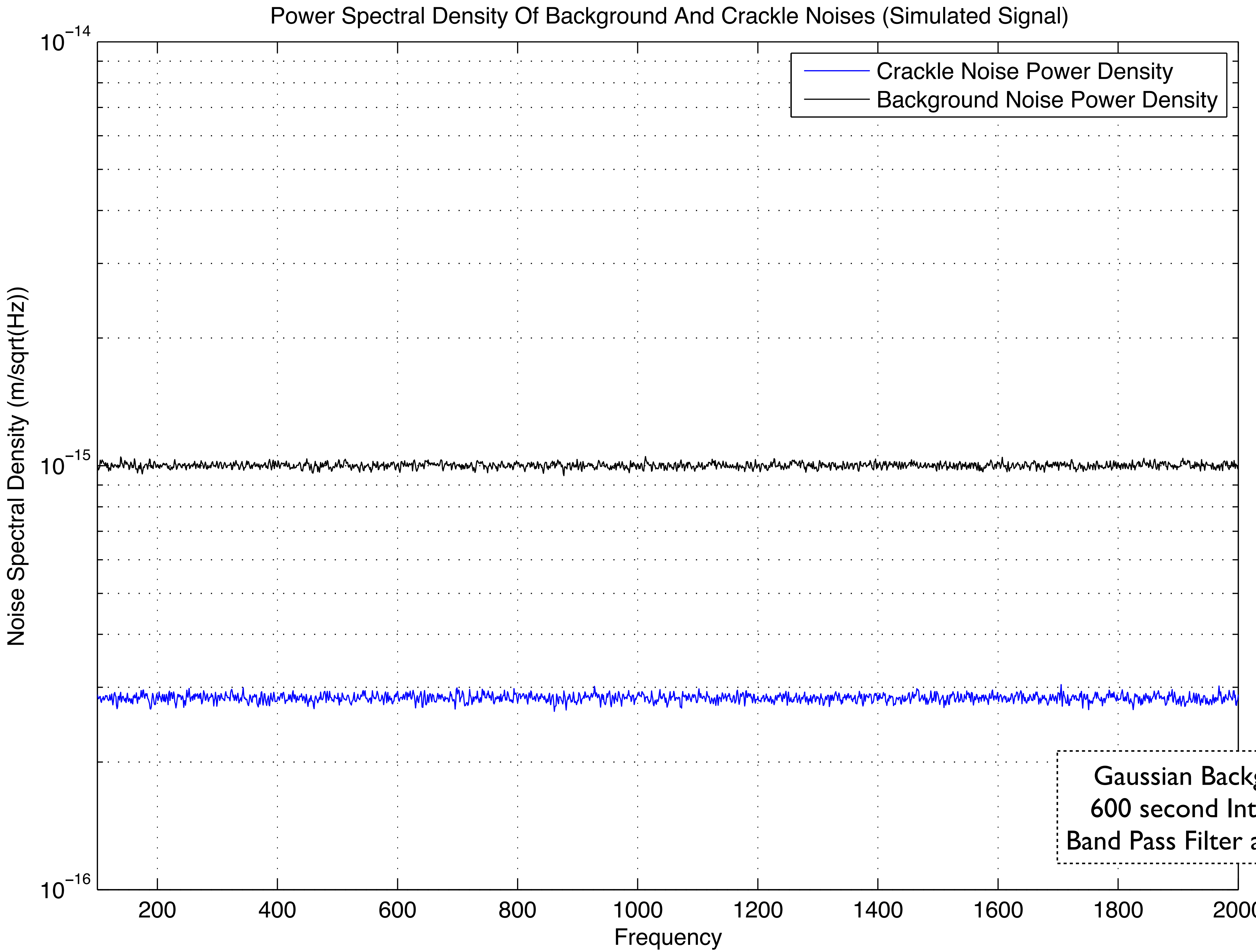
$$2\cos(2\omega_d t) \cdot dx_f^2$$

- Can make a statistical statement about the significance of the offset

Analysis


Min Alpha Value For Which We Can Be 95% Sure We See Crackle (Simulated Signal)
Alpha Value ("amount of crackle")
Background Noise Spectral Density (m/sqrt(Hz))
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-15}
10^{-14}
10^{-13}
10^{-12}
Gaussian Background Noise
600 second Integration Time
Band Pass Filter at 400Hz-500Hz

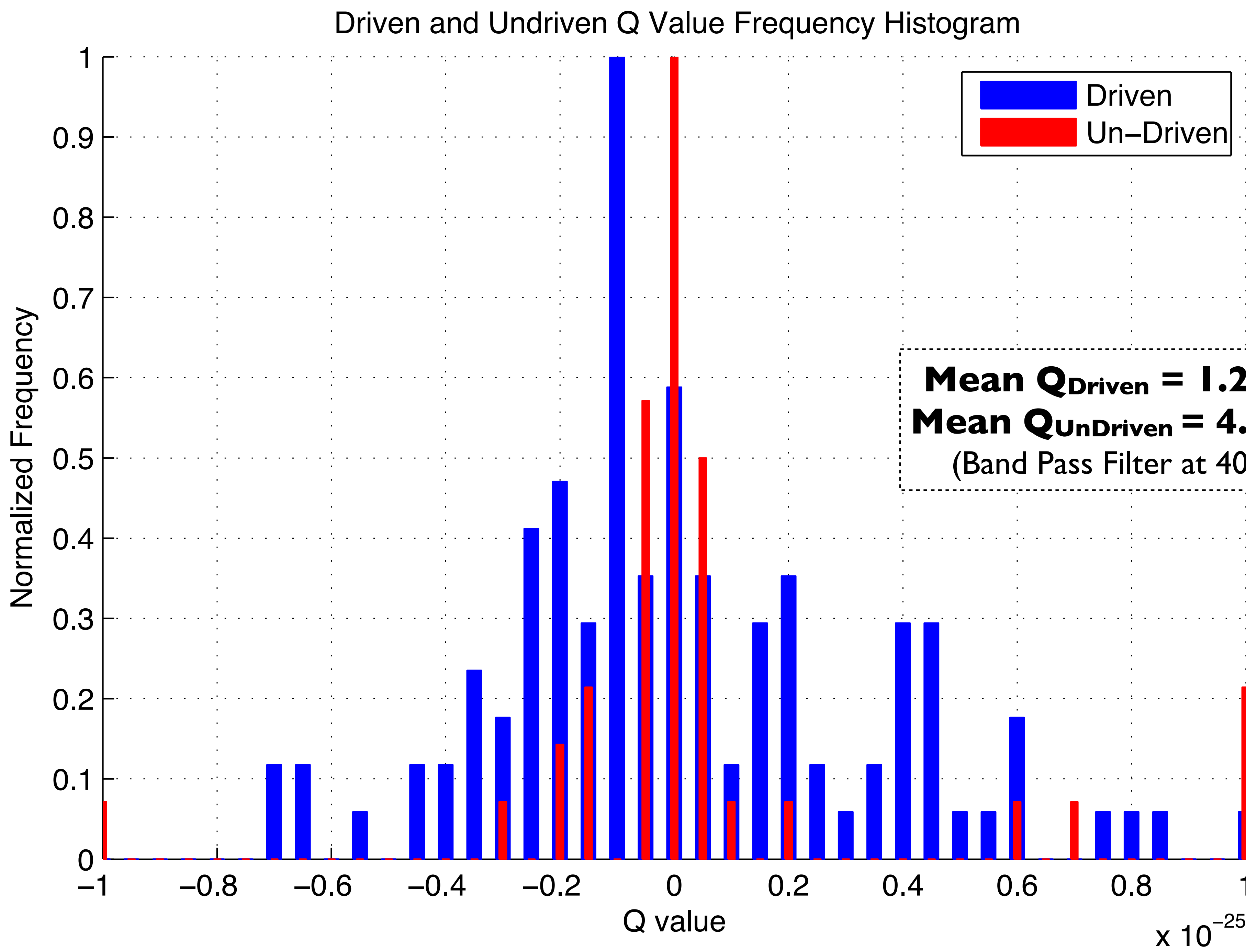
Analysis



Gaussian Background Noise
600 second Integration Time
Band Pass Filter at 400Hz-500Hz

Our First Data

- 2 hrs of Driven and 1 hr Un-Driven Data



Mean $Q_{Driven} = 1.22 \cdot 10^{-27}$ m^2
Mean $Q_{UnDriven} = 4.53 \cdot 10^{-27}$ m^2
(Band Pass Filter at 400Hz-500Hz)

Our First Data

- 95% confidence bounds for the difference in Qs is $3.317 \cdot 10^{-27} \pm 1.588 \cdot 10^{-26}\ m^2$
- $Q_{max} = 1.919 \cdot 10^{-26}\ m^2$
- At 100Hz, max noise density would could be seeing: $1.385 \cdot 10^{-14}\ ^{m}/_{\sqrt{Hz}}$

Thank You

- The NSF, LIGO, and Caltech SFP
- Eric Quintero and Rana Adhikari