LIGO

# Feedforward Seismic Noise Cancellation At The 40M Interferometer

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LIGO SURF Presentations, 2015

# Outline

# Motivation

- Filter out Seismic Noise from the 40m Interferometer
- Construct a feedforward online IIR Wiener filter
  - IIR Wiener filters are ideal
  - We want an online filter so that noise will then be accounted for in real time
  - Feedforward ensures that the filter will be implemented as the disturbance travels through the system

# Feedback vs. Feedforward

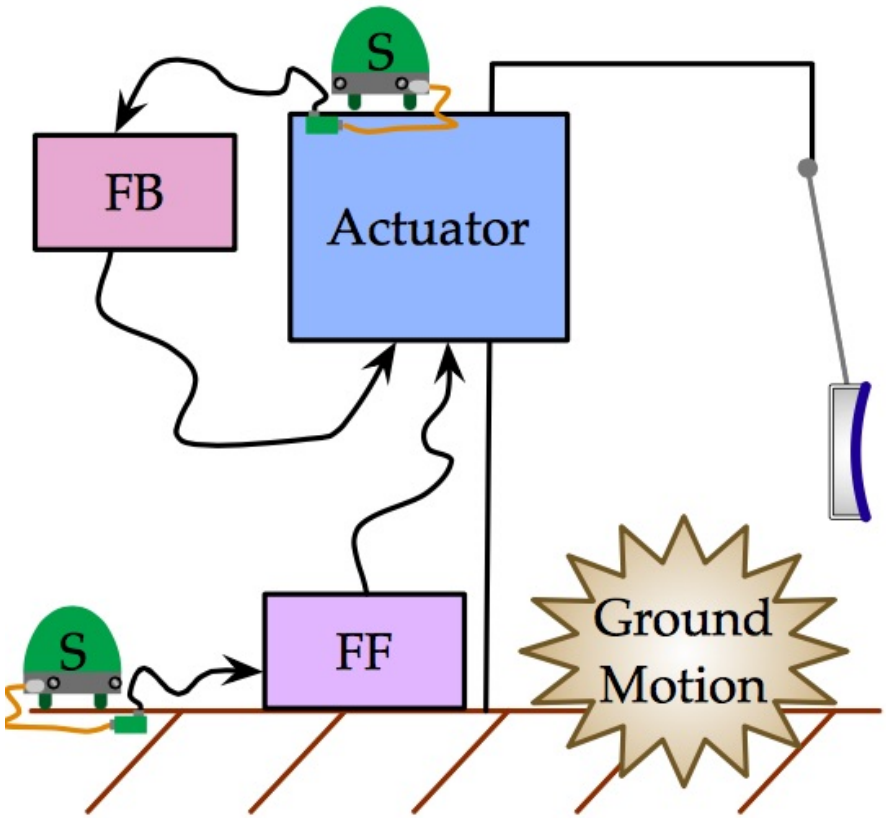
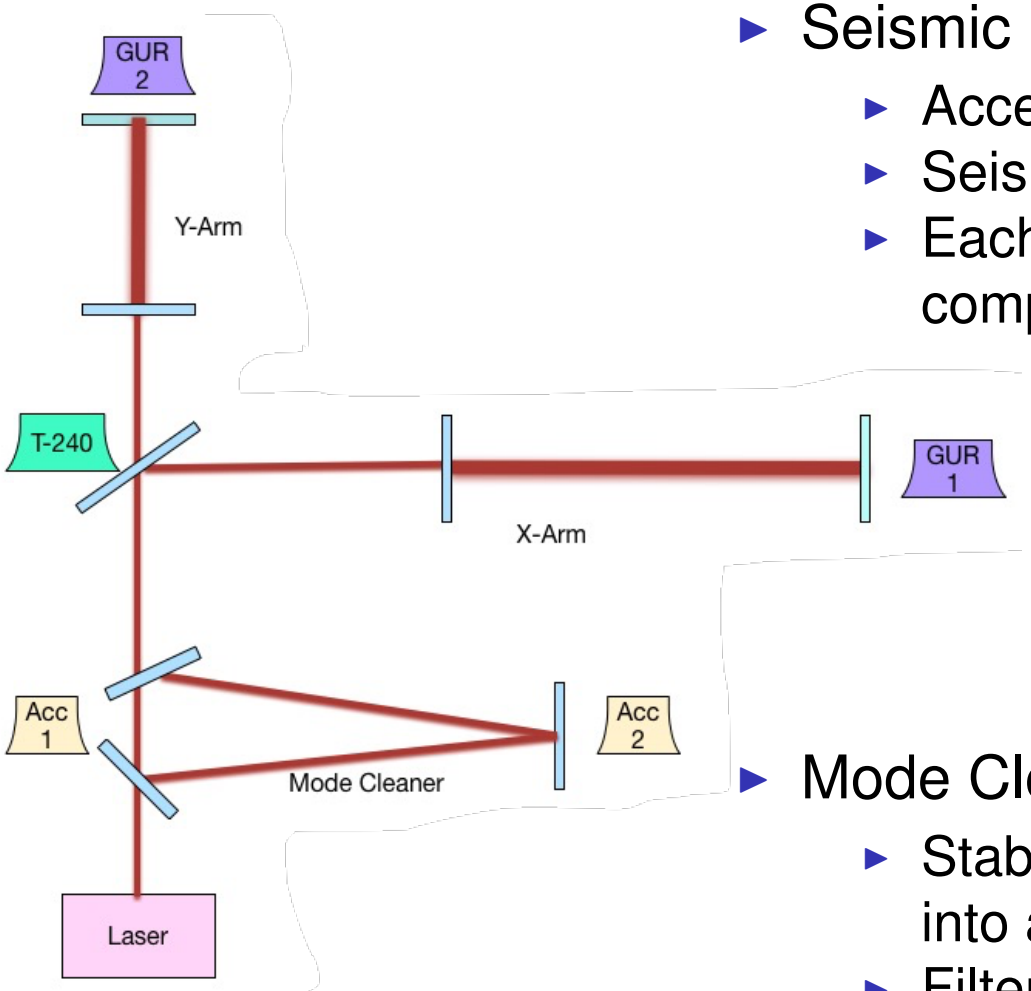


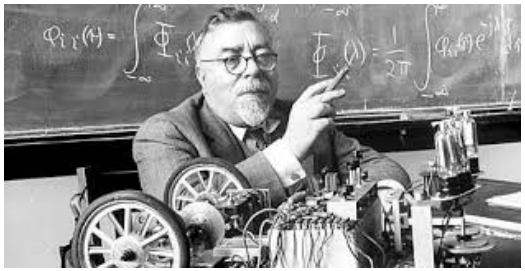

Figure: The differences between a feedback loop and a feedforward loop [1]

# Noise Sources and Detection




- Seismic Noise
  - Accelerometers
  - Seismometers
  - Each has an X, Y, and Z component
- Mode Cleaner
  - Stabilizes laser as it goes into arms
  - Filtering out noise from mode cleaner will also reduce noise in the arms

# Wiener Filtering



- Target Signal is what we're trying to detect
- Witness Signal is what we use to detect the target signal
- We are trying to determine the error signal to filter it out

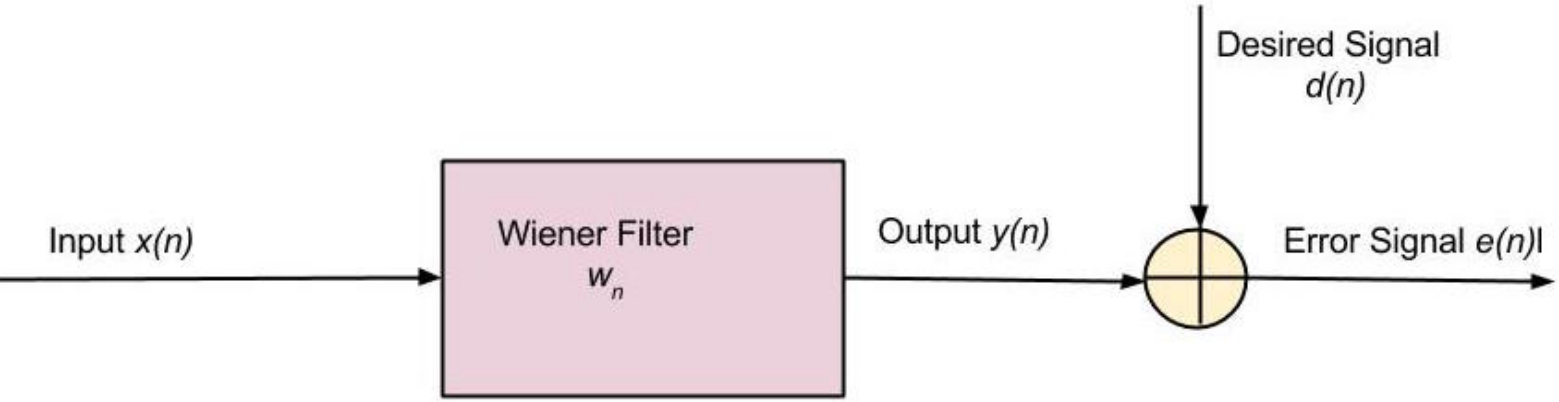



Figure: Wiener Filter

# Wiener Filtering

- Wiener filters minimize the following equation:

$$\xi = < \vec{d}(n)^2 > -2\vec{\omega}^T\vec{p} + \vec{\omega}^T R\vec{\omega} \qquad (1)$$

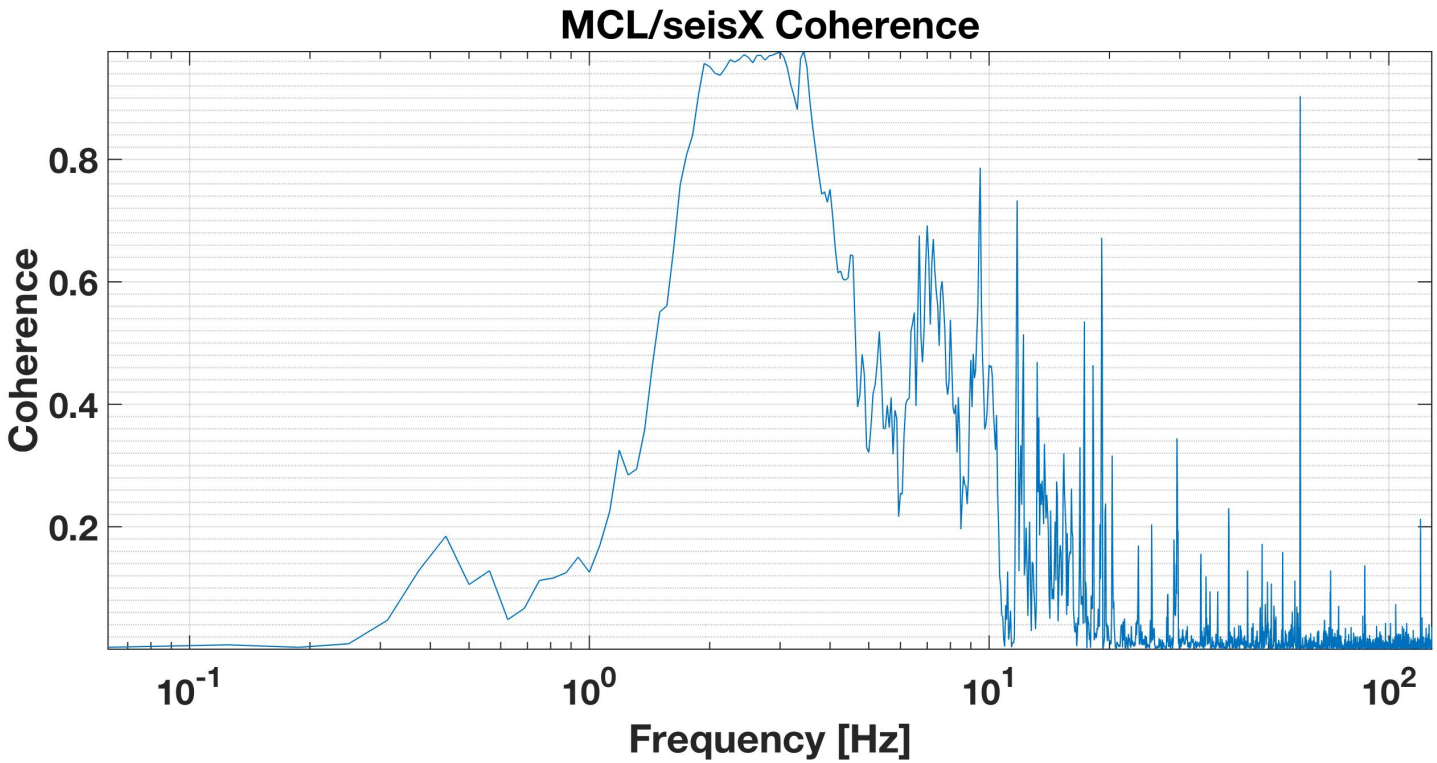
  - $\xi$ is the RMS of the error signal
  - $d$ is the signal to filter
  - $\vec{\omega}$ is the Wiener filter to solve for
  - $\vec{p}$ is a cross-correlation vector between witness and target signals
  - $R$ is witness correlation matrix between witness signals
- Coefficients are then applied to data in Matlab

# Pre-Filtering Techniques

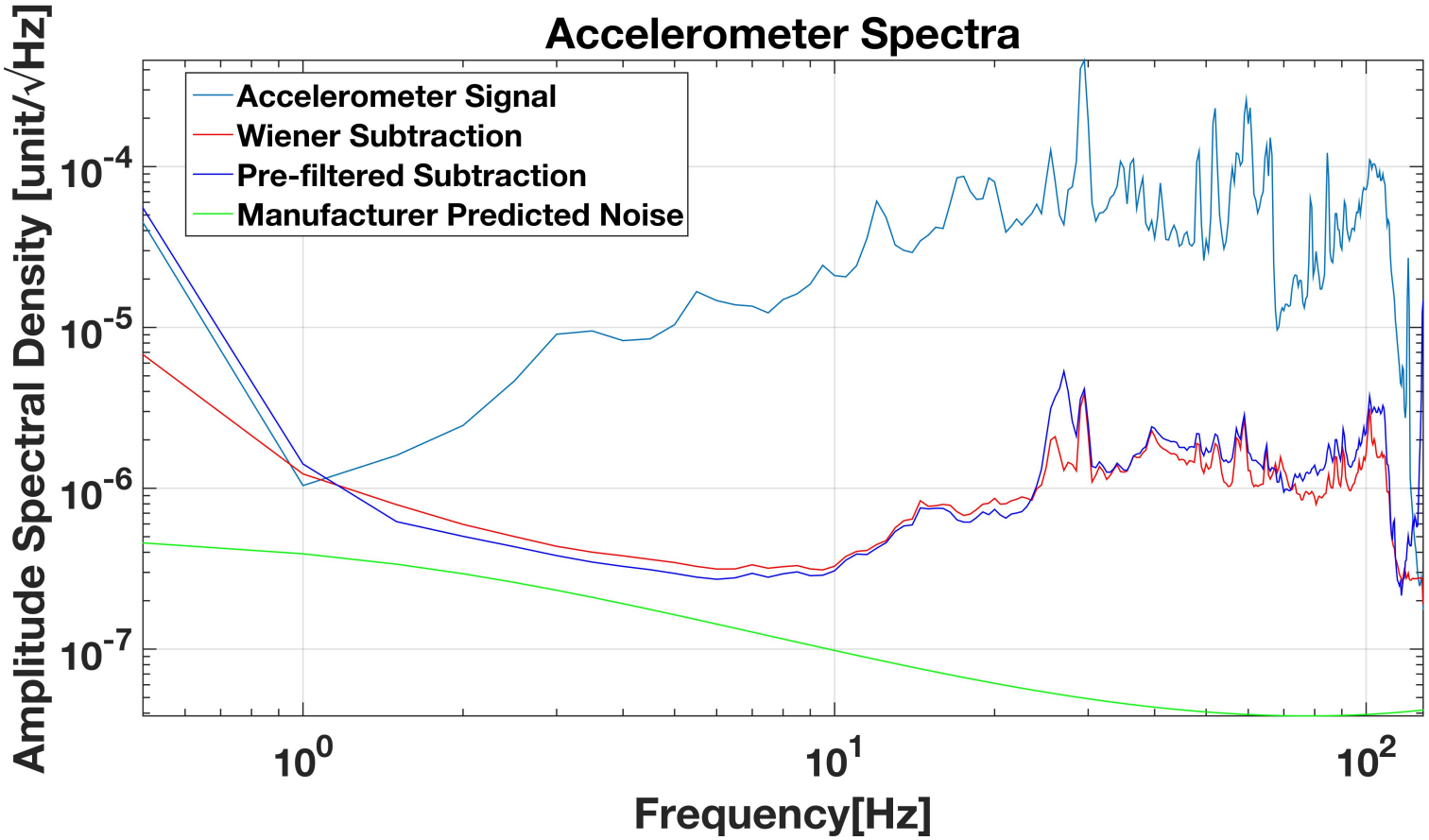
- Goal is to optimize the RMS, so it will affect the Wiener filter
- Bandpass filter was used
- Elliptic: Control filter order, passband ripple, and stopband attenuation

# Pre-Filtering Method

- Find frequency range from coherence levels cutoff



# Pre-Filtering Results

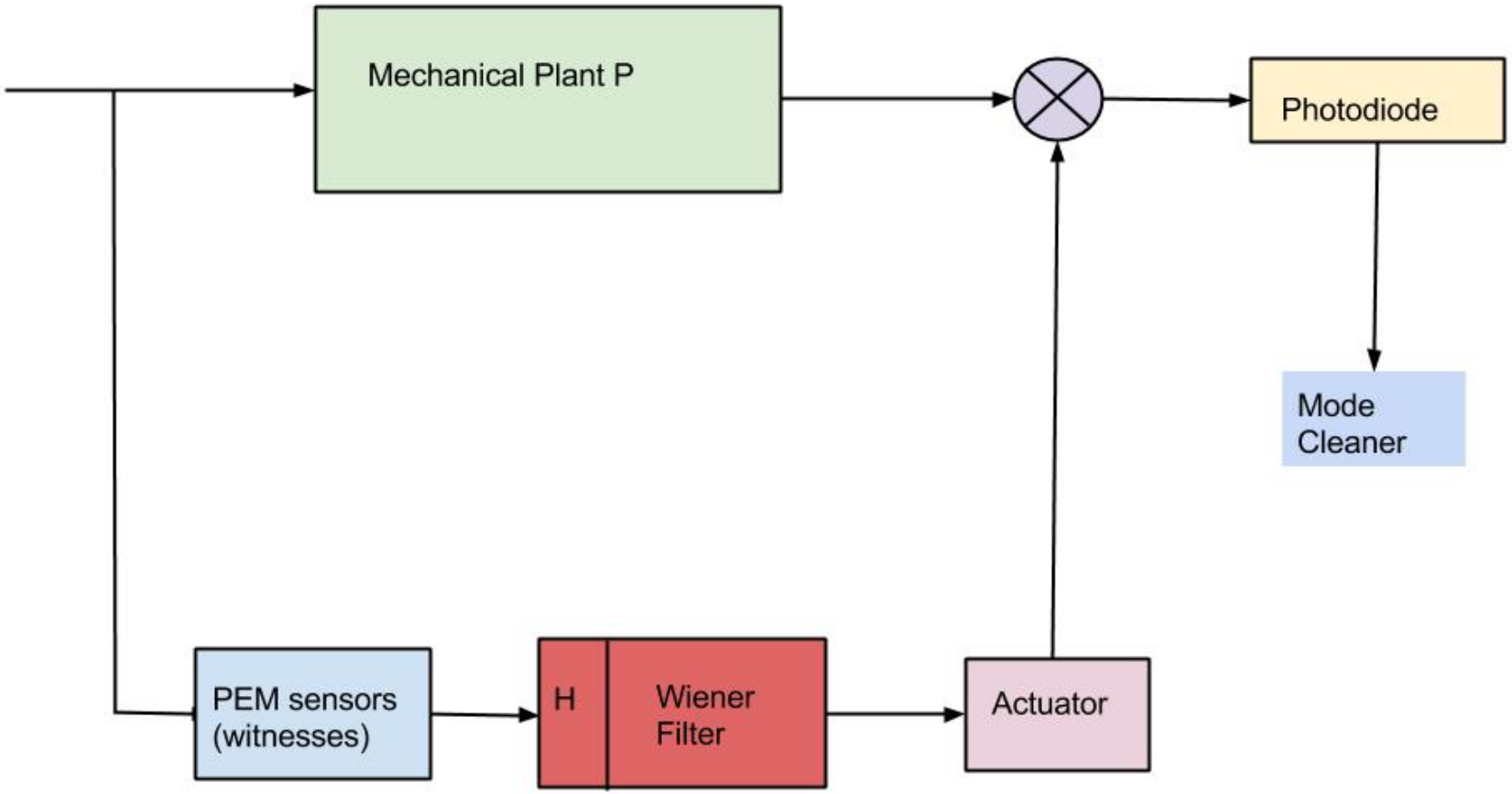



The use of a pre-filter showed little improvement from a Wiener filter without pre-filtering

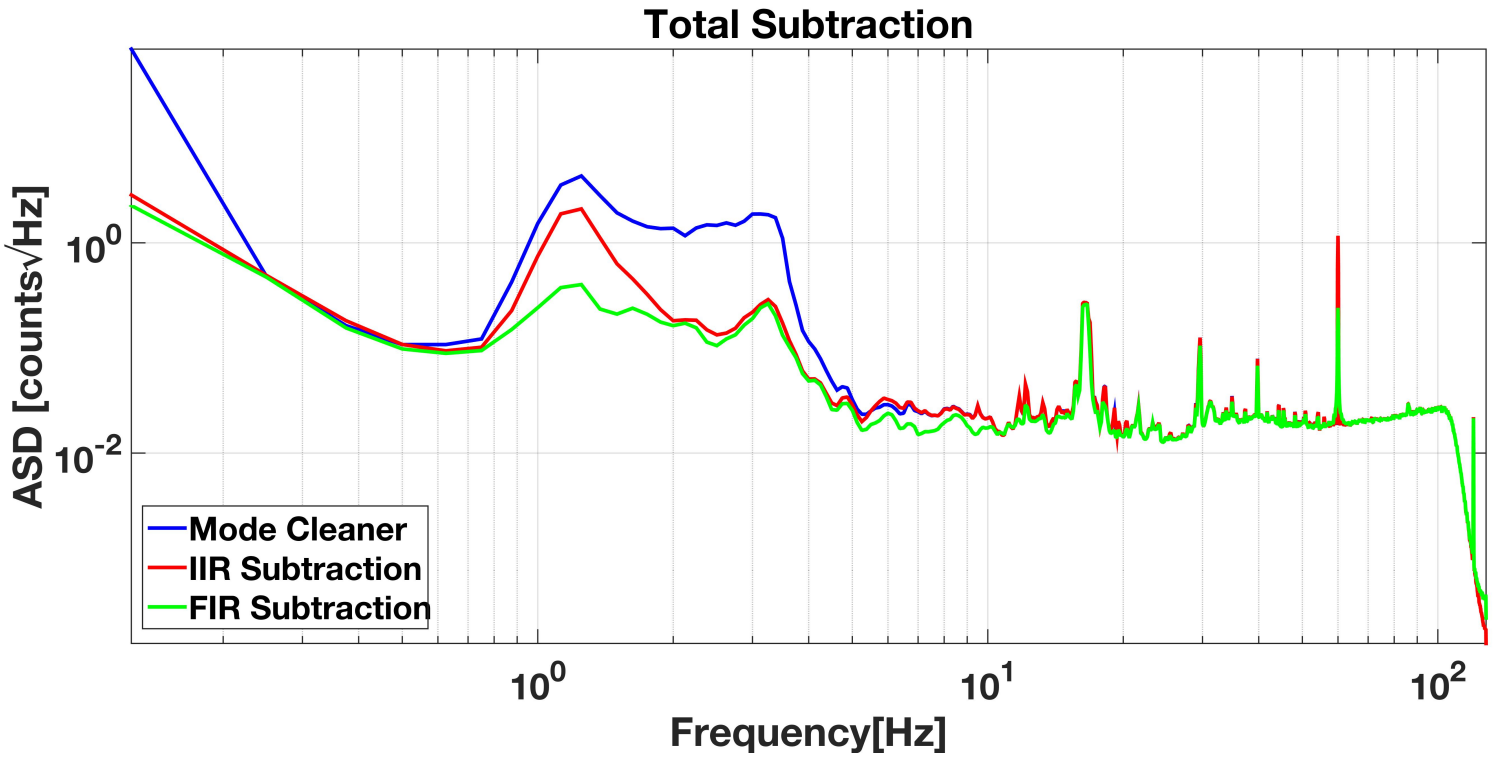
# Online vs. Offline Subtraction

- Online subtraction is ideal because then the mirrors will be moved as little as possible
- Online allows for the system to be mechanically optimized
- Offline subtraction can only work with previously acquired data

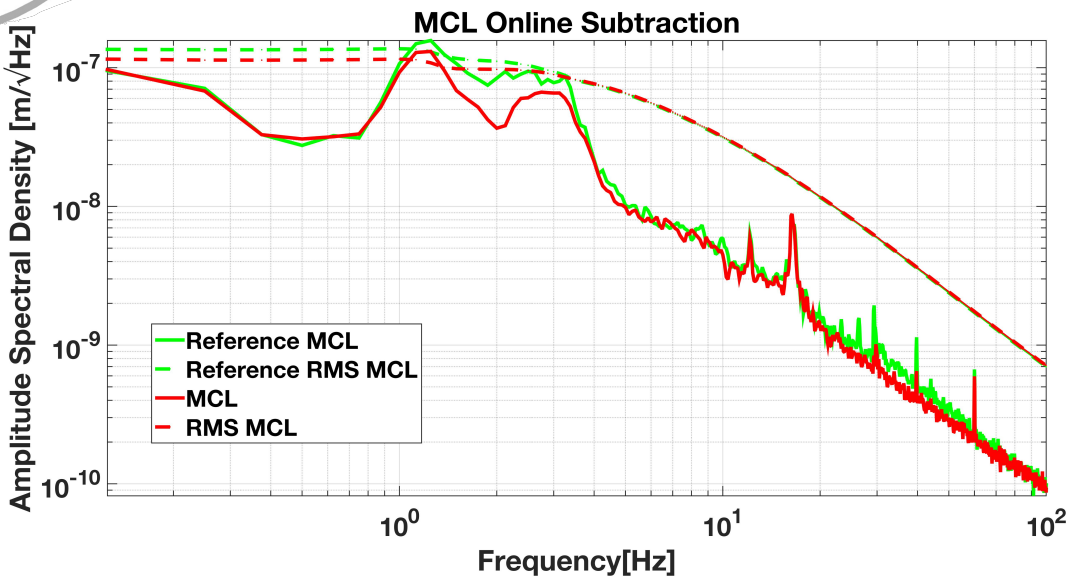
# Implementing Online Subtraction

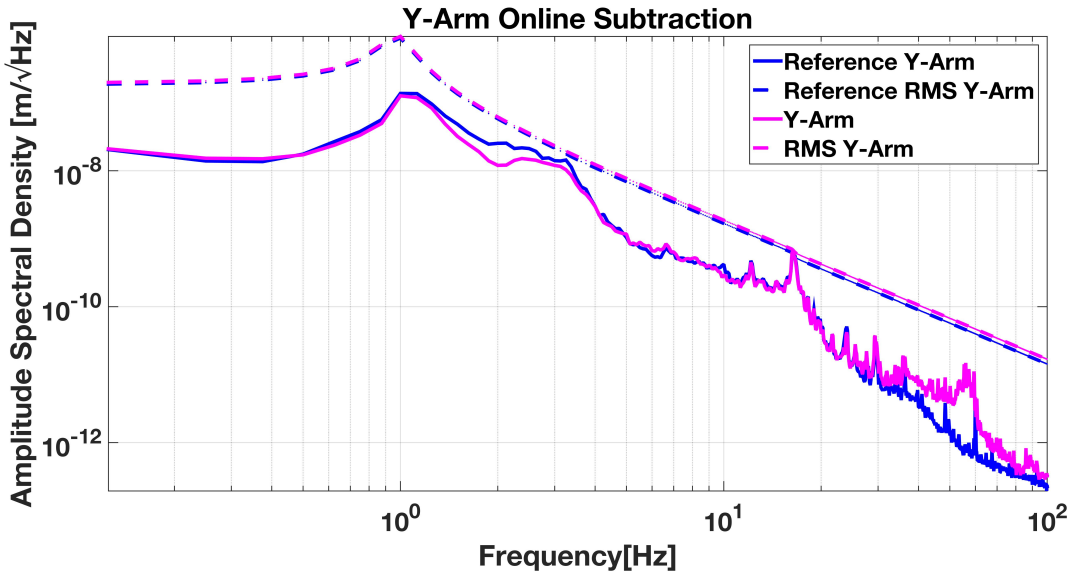


# Offline MCL Subtraction



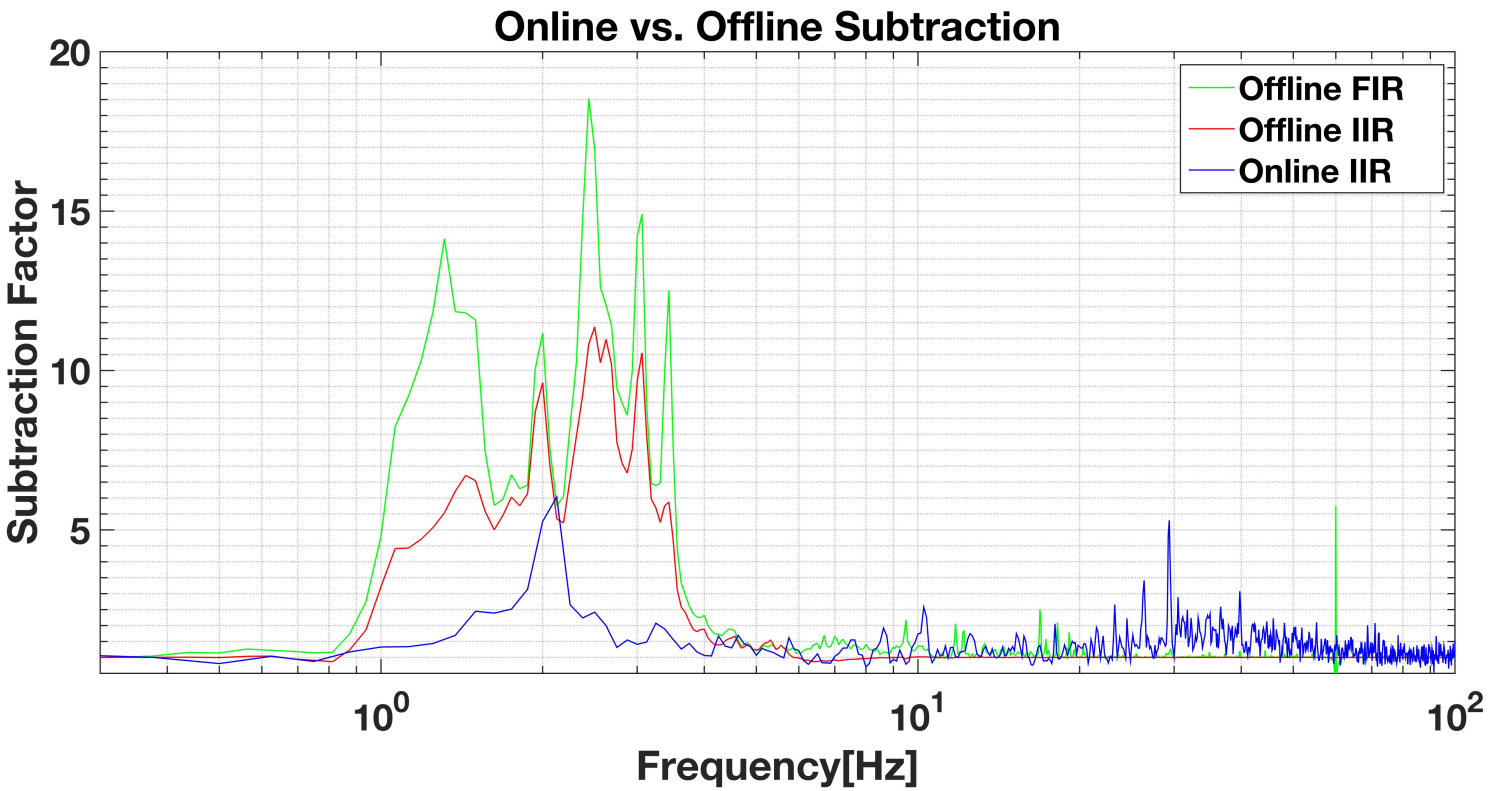
# Online MCL Subtraction




Results of the online subtraction of the mode cleaner and the subsequent Y-Arm response

# Online vs. Offline



# Conclusion

- Steps towards methodical pre-filtering
- Online IIR Wiener filtering was implemented

# Acknowledgments


- My Mentors: Eric, Rana, and Koji
- Ignacio
- LSC and the NSF

# For Further Reading I

J. Driggers, M. Evans, K. Pepper, and R. Adhikari, *Active Noise Cancellation in a Suspended Interferometer*. arxiv:1112.2224. (December 2011).