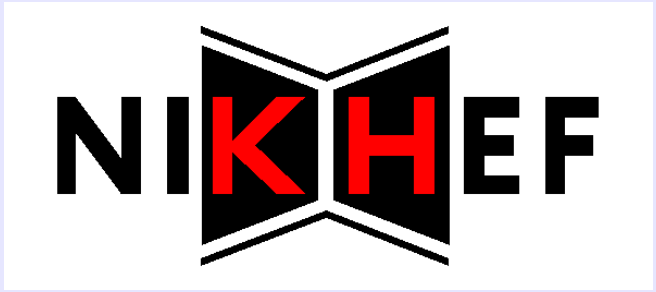
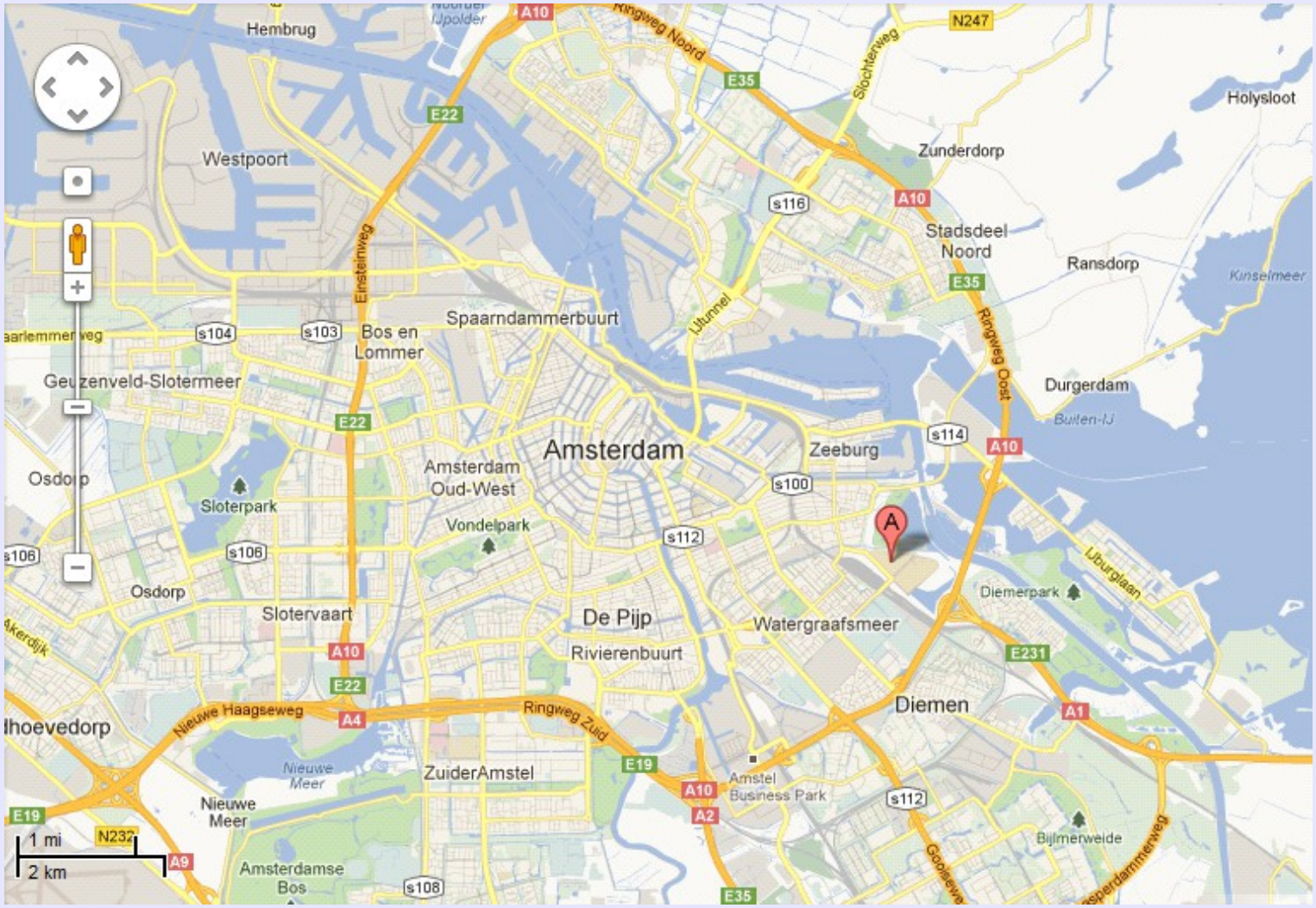


ADC Noise Reduction and Characterization of a Compact Michelson Interferometer

Kristen Zych
University of Florida
Research Experience for Undergraduates

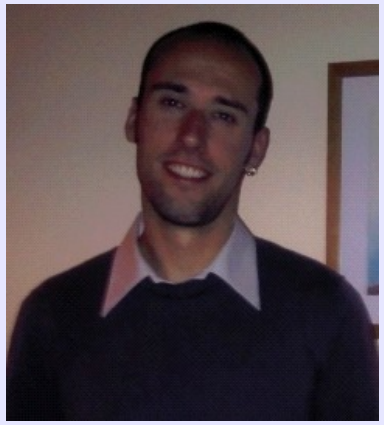
- Nikhef
- National Institute for Subatomic Physics (*Nationaal instituut voor subatomaire fysica)*
- In collaboration with VIRGO

- Located in Amsterdam, the Netherlands



Dr. David Rabeling

- Focus: Virgo, noise analysis



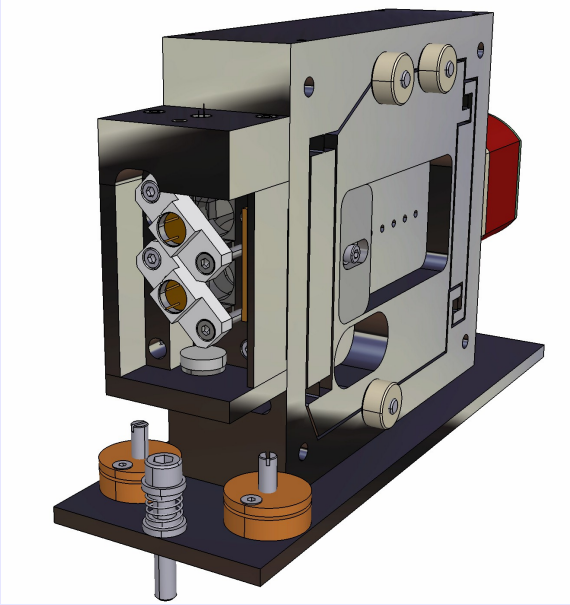
Dr. Jo van den Brand

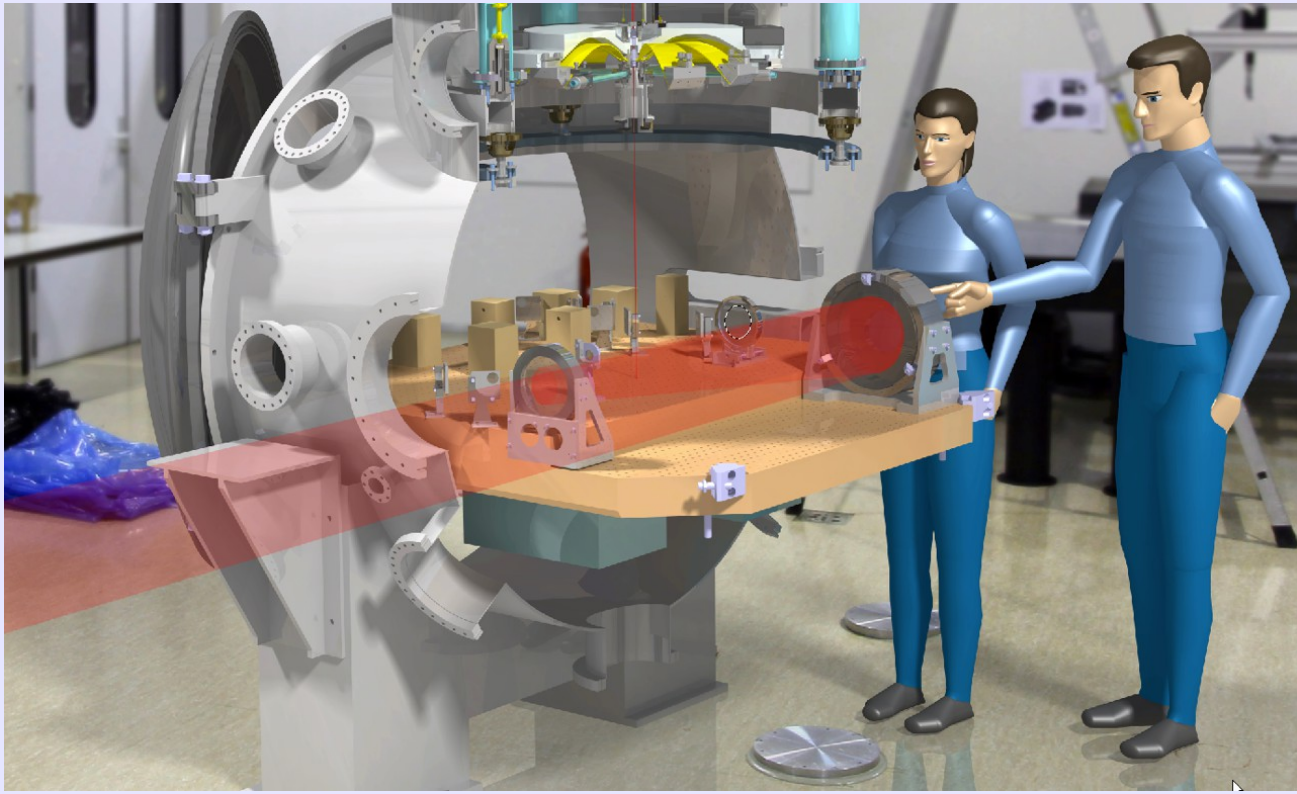
- Focus: Virgo, LISA, LHCb

Mark Beker

- Graduate student

Motivation





- A MultiStage Attenuation System (MultiSAS) is being built
- Needs performance check
- Commercial seismometer or geophone isn't enough
- Need low noise readout for monolithic accelerometer

Weeks 1-3

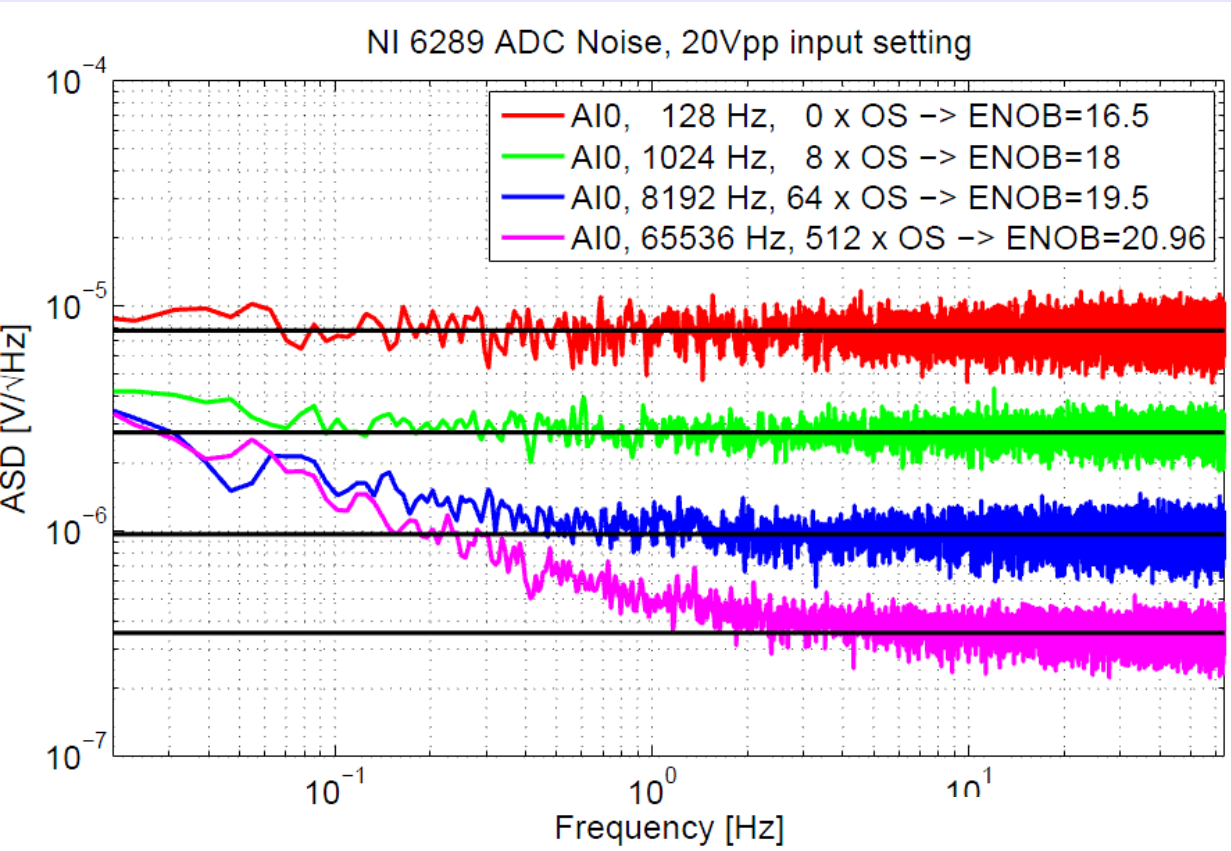
Overview

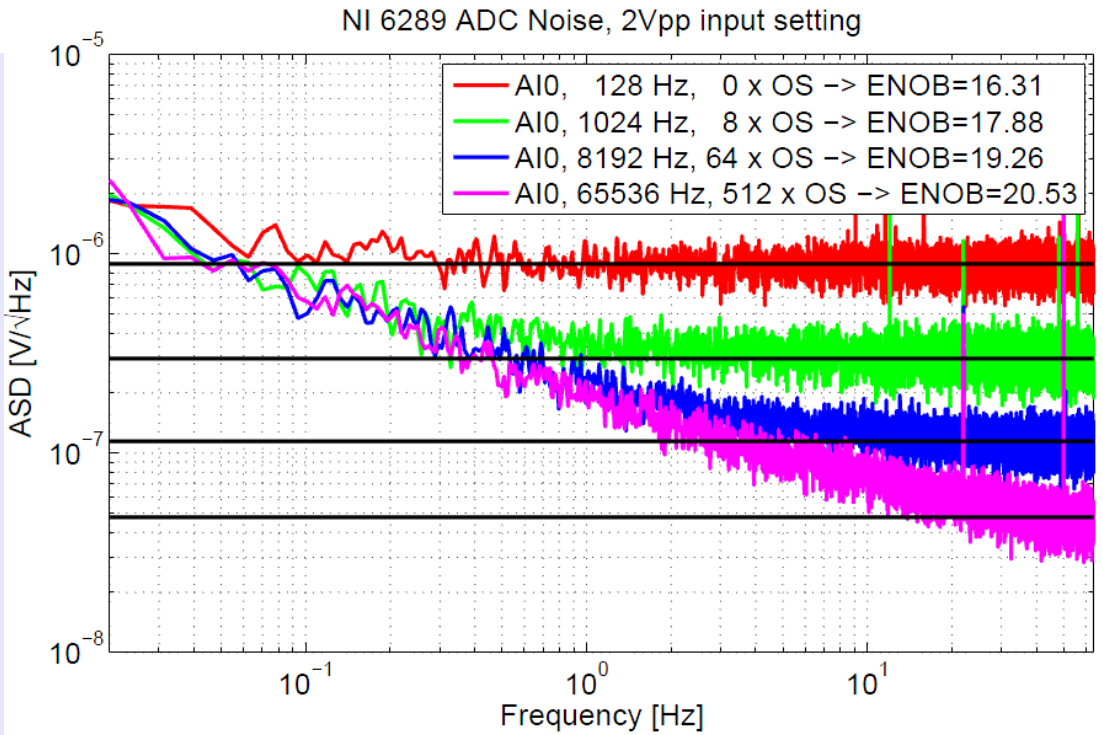
- Learned how to use LabView
- Got comfortable with frequency space, PSD
- ADC quantization noise measurements

- Quantization noise comes from digitizing the waveform $\Delta = \frac{Vpp}{2^N}$
- Evaluated the dynamic range of the ADC with ASD
- Oversampling
  - Sampling at a rate much higher than the target frequency $OSR = \frac{f_{os}}{f_s}$
- Decimation
  - Averaging the data
- After a short derivation, we get this equation:

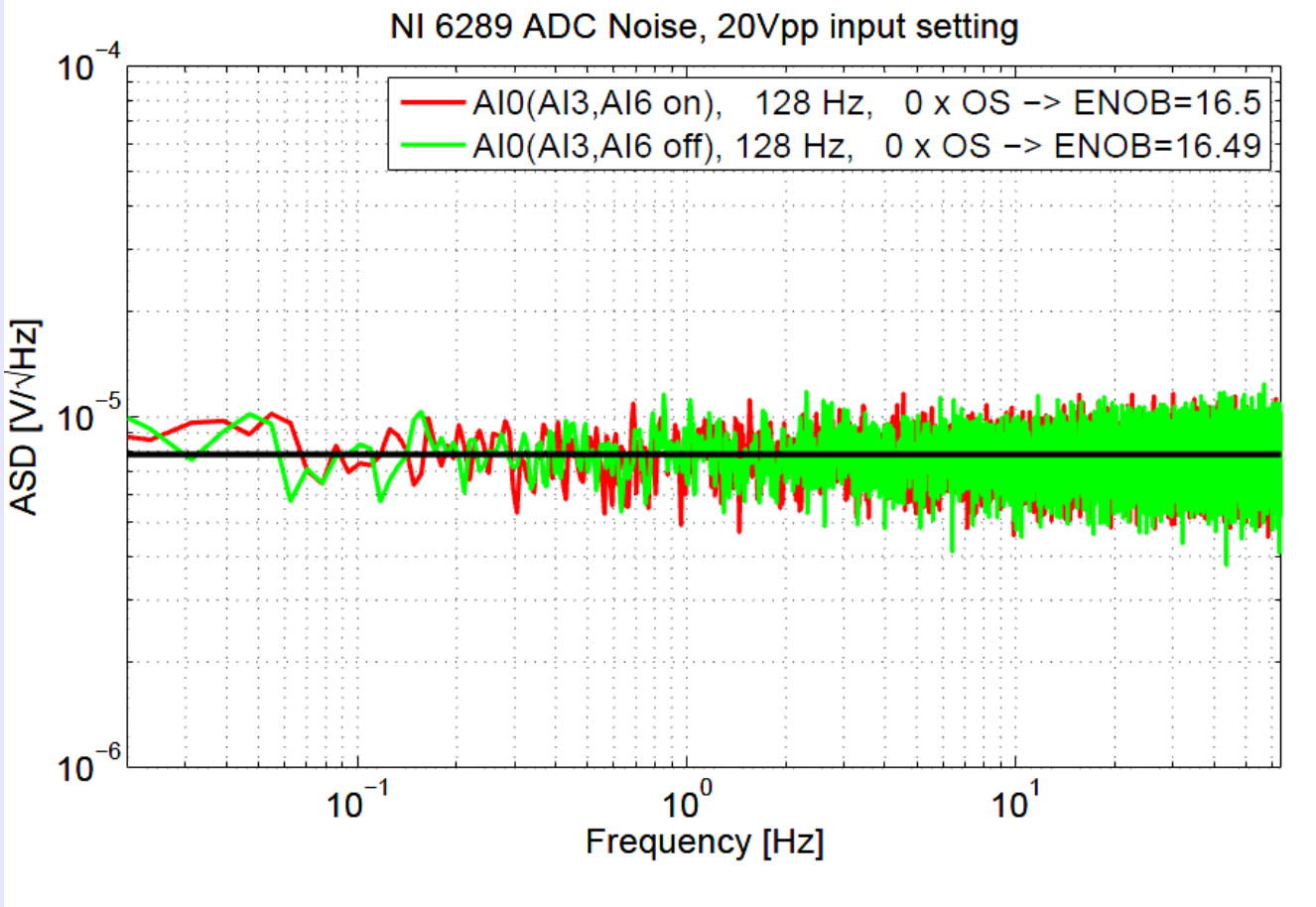
$$N = -\frac{1}{2}\frac{\log(OSR)}{\log(2)} - \frac{1}{2}\frac{\log(12 \cdot ASD_{noise})}{\log(2)} + \frac{\log(Vpp)}{\log(2)}$$

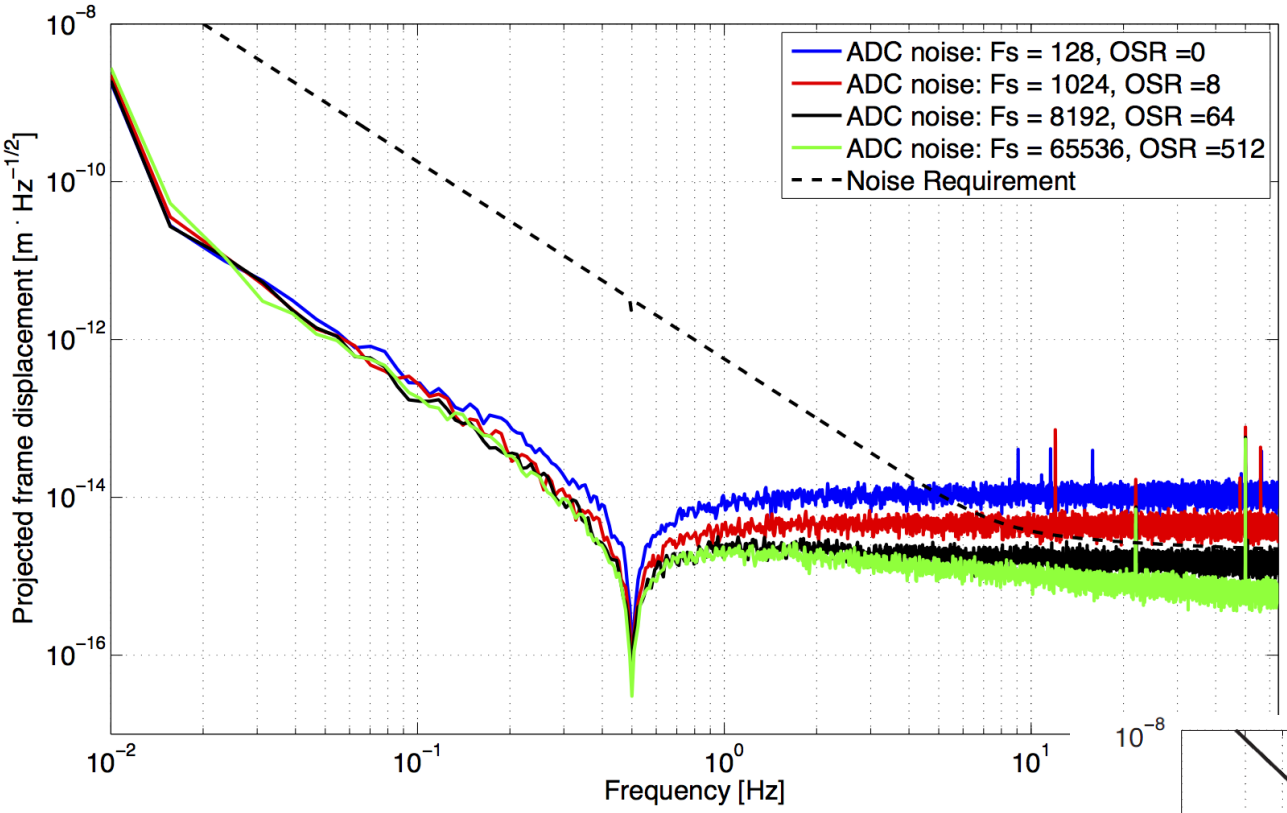
- Decreased quantization noise
- Could not sample faster than 100 kS/s
- Not enough memory

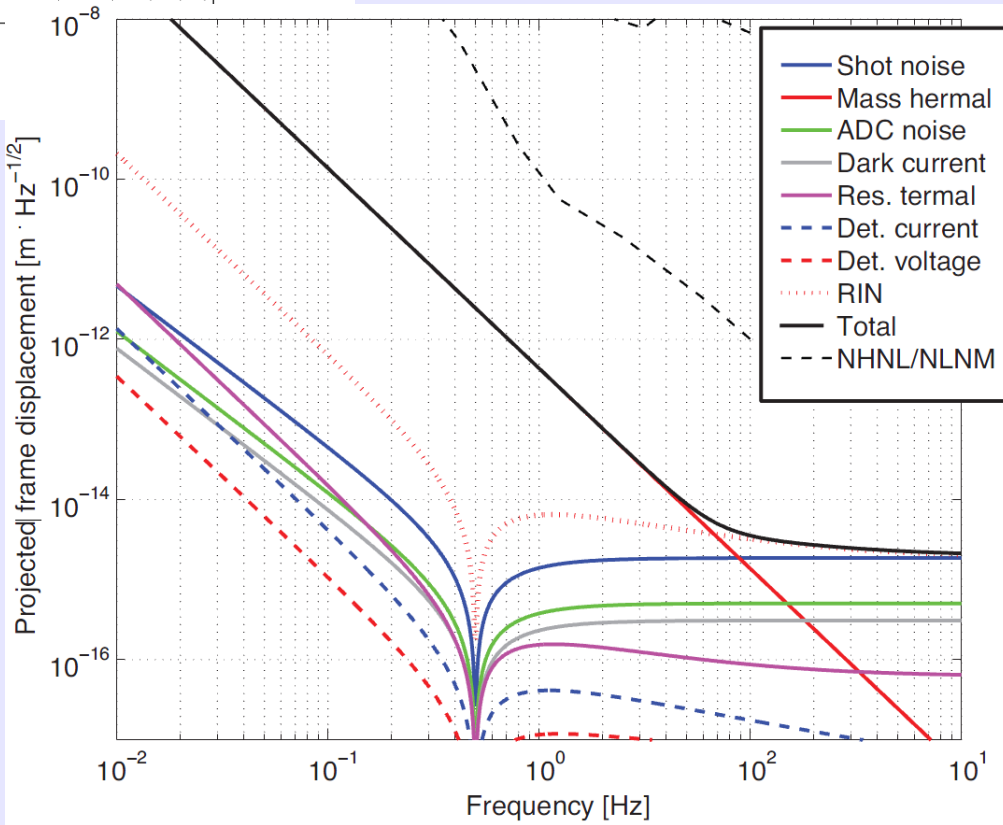

NI 6289 ADC Noise, 20Vpp input setting
AI0, 128 Hz, 0 x OS -> ENOB=16.5
AI0, 1024 Hz, 8 x OS -> ENOB=18
AI0, 8192 Hz, 64 x OS -> ENOB=19.5
AI0, 65536 Hz, 512 x OS -> ENOB=20.96
ASD [V/√Hz]
Frequency [Hz]


NI 6289 ADC Noise, 2Vpp input setting
AI0, 128 Hz, 0 x OS -> ENOB=16.31
AI0, 1024 Hz, 8 x OS -> ENOB=17.88
AI0, 8192 Hz, 64 x OS -> ENOB=19.26
AI0, 65536 Hz, 512 x OS -> ENOB=20.53
ASD [V/√Hz]
Frequency [Hz]

- Using fewer channels did not decrease the noise level further




ADC noise: Fs = 128, OSR =0
ADC noise: Fs = 1024, OSR =8
ADC noise: Fs = 8192, OSR =64
ADC noise: Fs = 65536, OSR =512
Noise Requirement
Projected frame displacement [m · Hz$^{-1/2}$]
Frequency [Hz]


Shot noise
Mass hermal
ADC noise
Dark current
Res. termal
Det. current
Det. voltage
RIN
Total
NHNL/NLNM
Projected frame displacement [m · Hz$^{-1/2}$]
Frequency [Hz]

Week 4

Overview

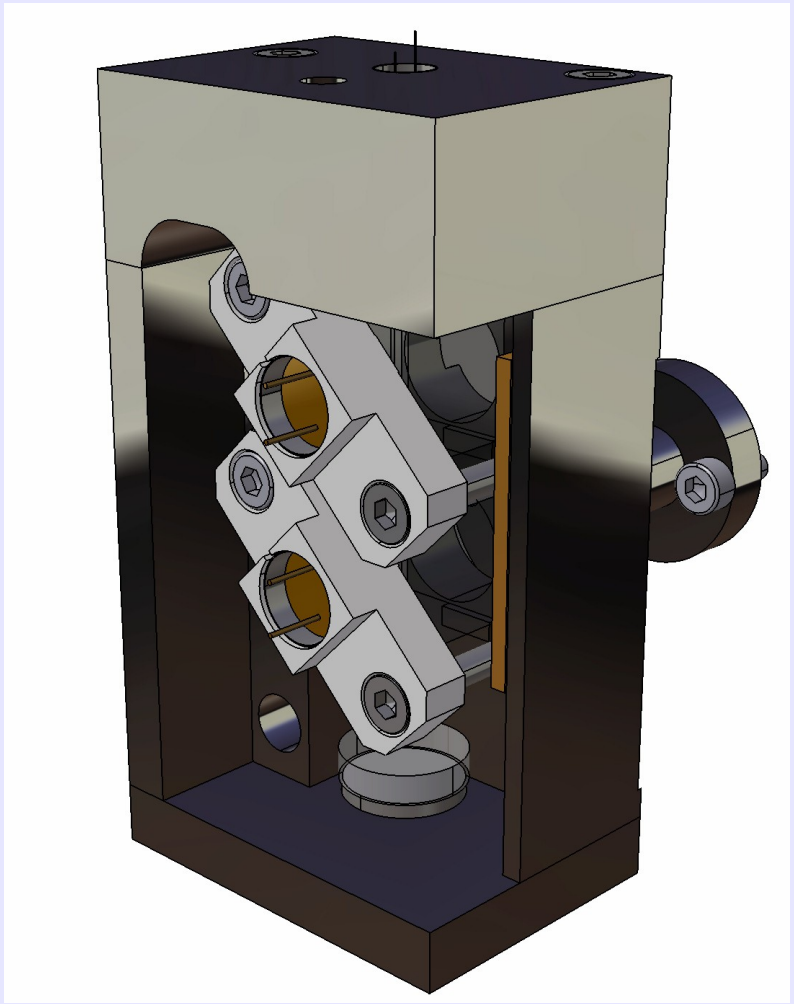
- Virgo week!
- Helped dig holes, lay cement, take measurements
- Relay

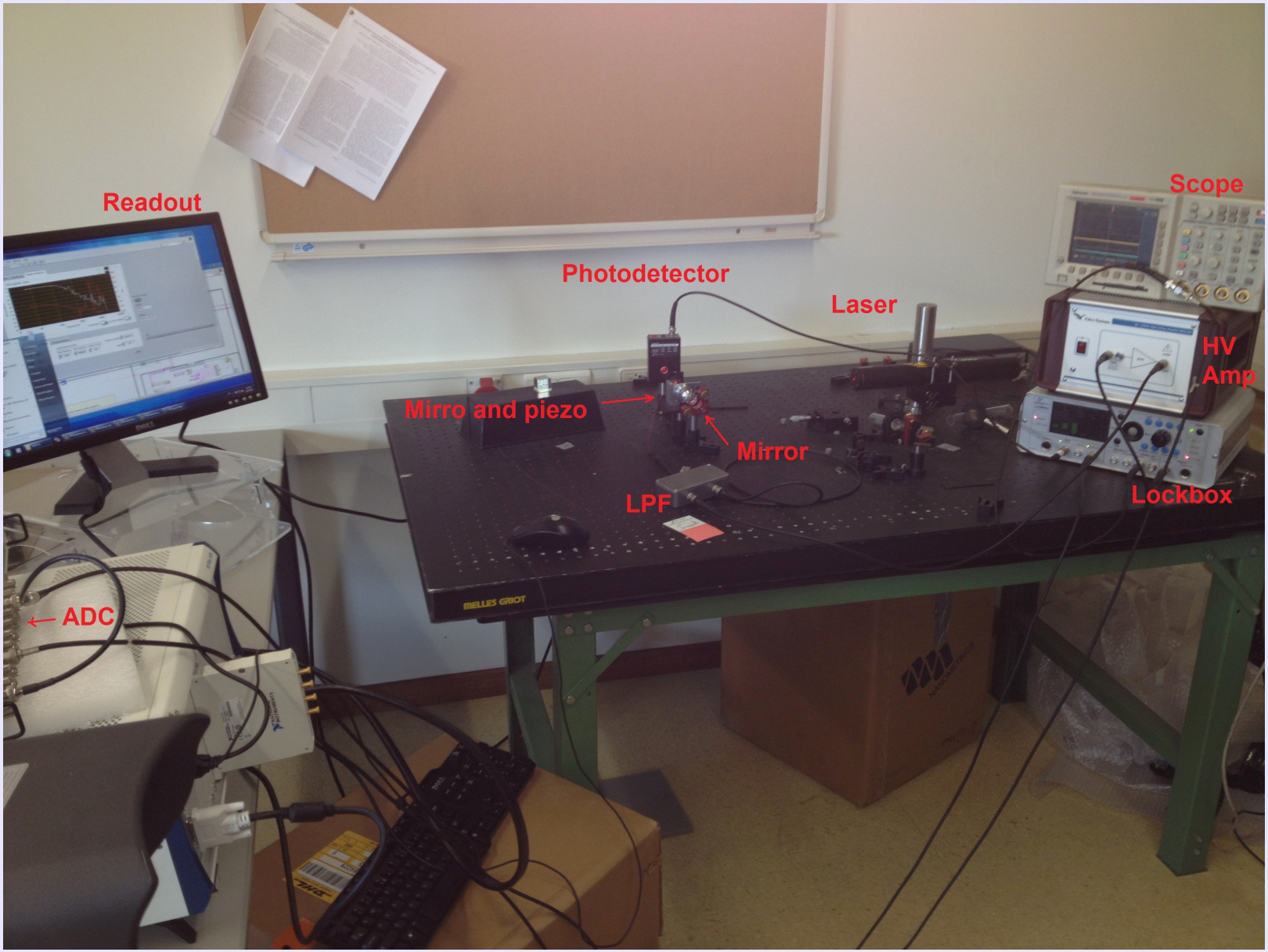
Weeks 5-7

Overview

- Set up interferometer
- Worked on Labview frequency response VIs
- Control Theory
- Took transfer functions

- Attempted to find the correct arm lengths for the interferometer
  - Paper
  - Optical stage
- Set up interferometer with HeNe laser
  - Long coherence length

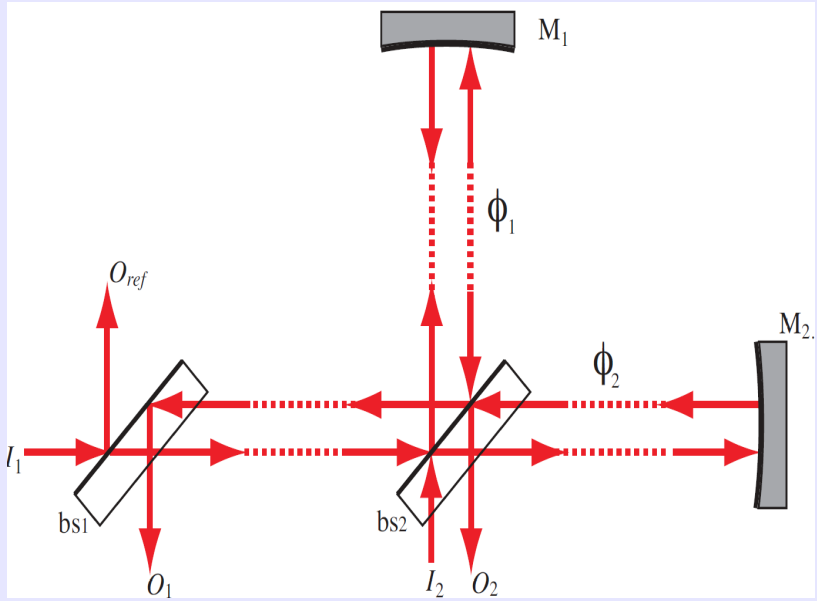


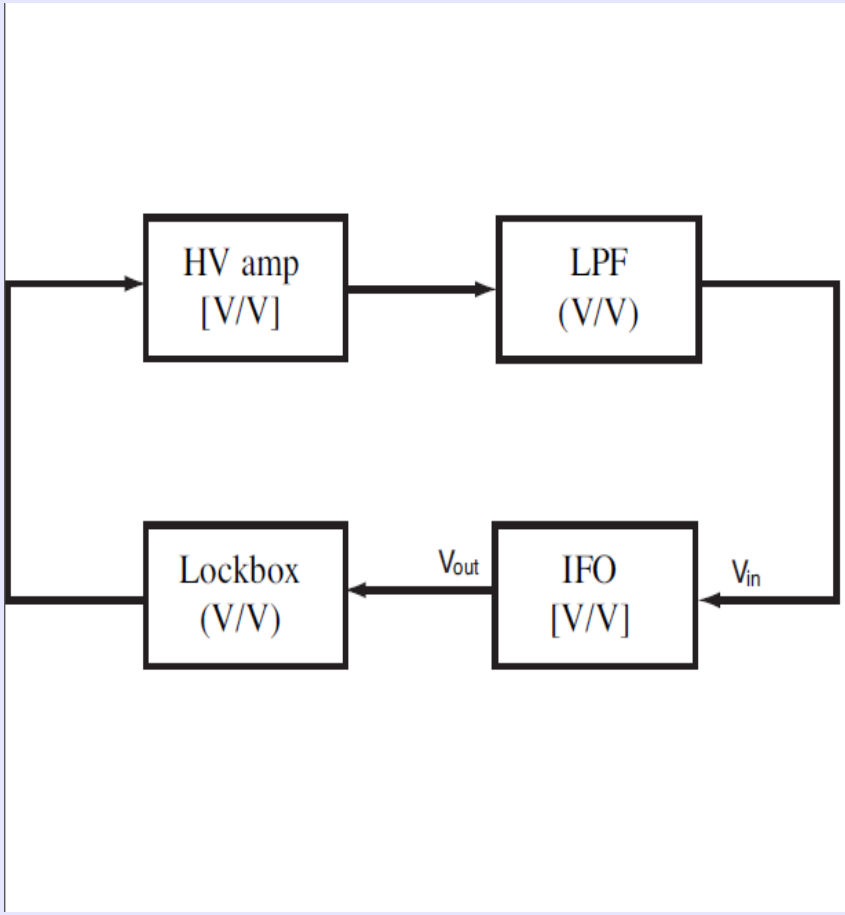

Readout
Scope
Photodetector
Laser
HV
Amp
Mirro and piezo
Mirror
LPF
Lockbox
ADC
MELLES GRIOT

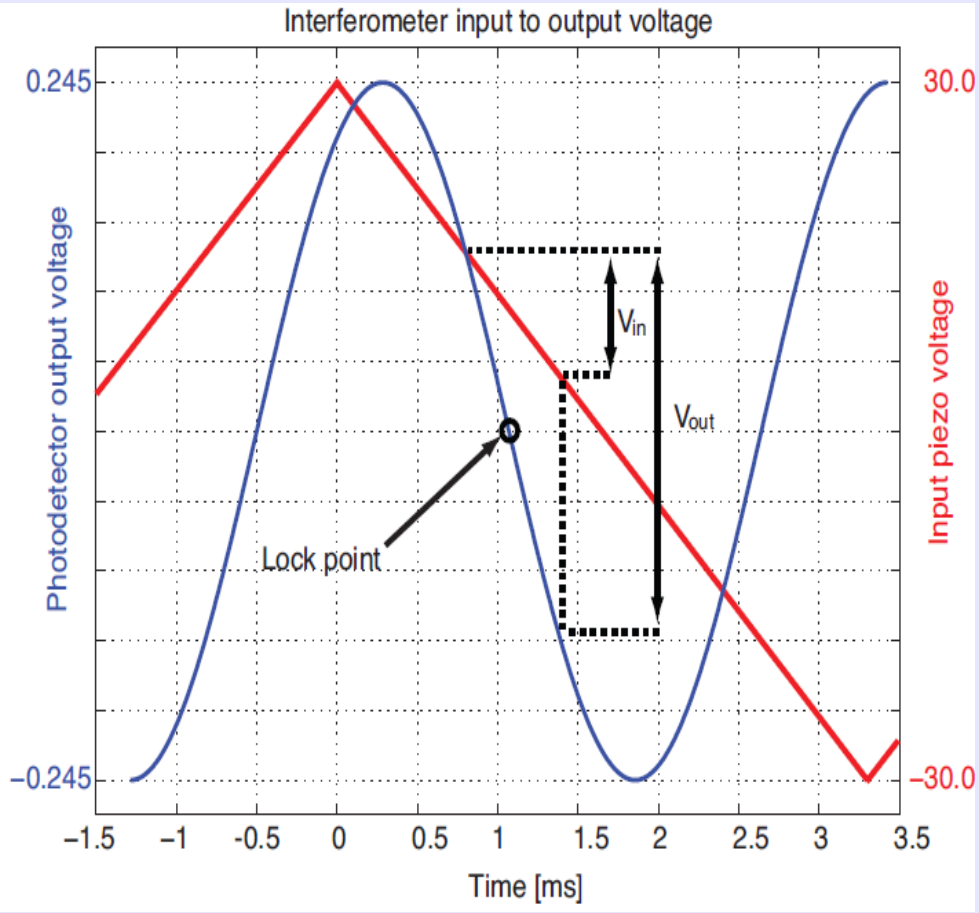
- Transfer functions exist in many forms and have many applications
- Frequency domain
- Find resonances
- Characterization of interferometer and environment

- Took transfer functions
  - LPF
  - Lockbox
  - HV Amp
  - Closed loop system

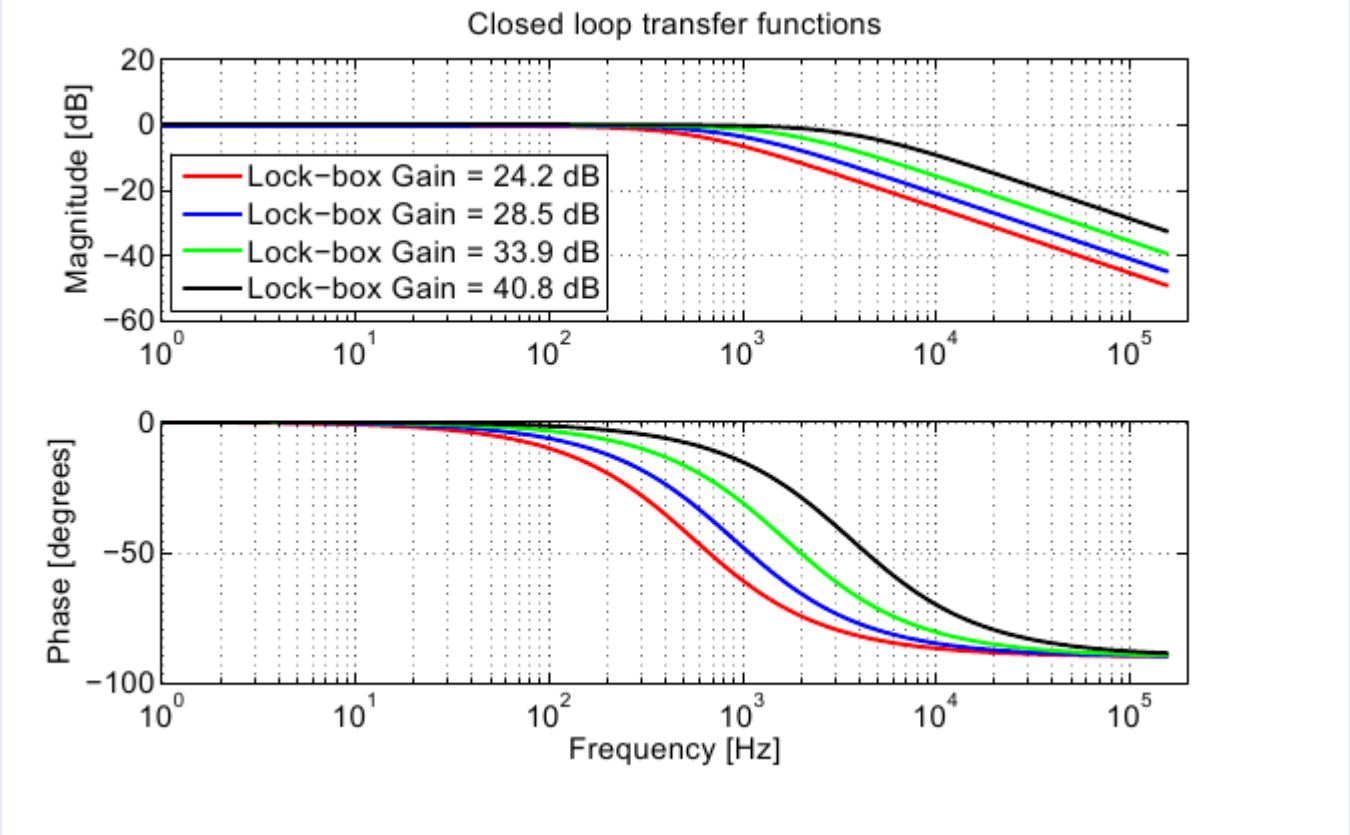
- Learned about control theory
  - Locking the interferometer



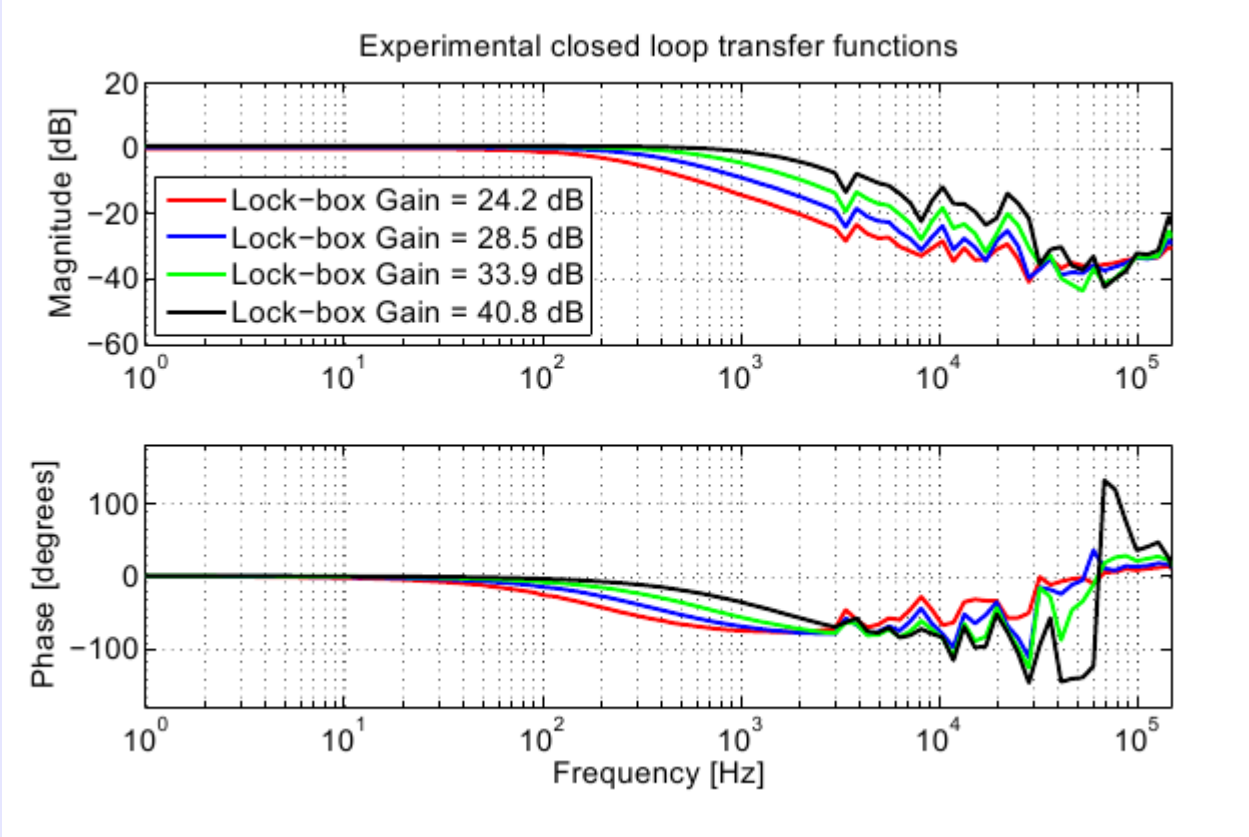




- We made a theoretical version of the loop in Matlab
- Bandwidth of 1.7kHz



- The experimental data had a bandwidth of 1.6kHz



- In conclusion, the ADC algorithm was implemented successfully and interferometer control system works as expected
- Further work will include
  - Getting arm lengths right for LED light source
  - Ultimately mounting the interferometer to the accelerometer

- Special thanks to David, Jo, Mark, and Mathieu

Questions?

Amsterdam Centraal

DB
Berlin Hauptbahnhof