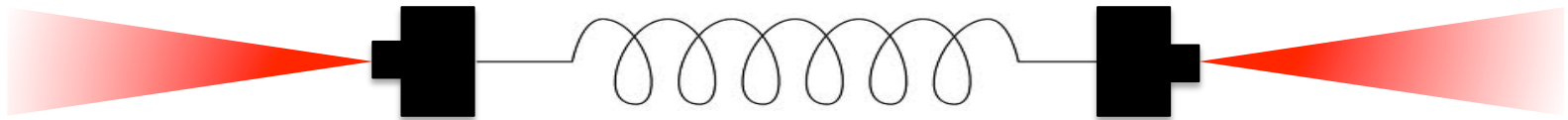


Transportation of Ultra-Stable Light via Optical Fiber



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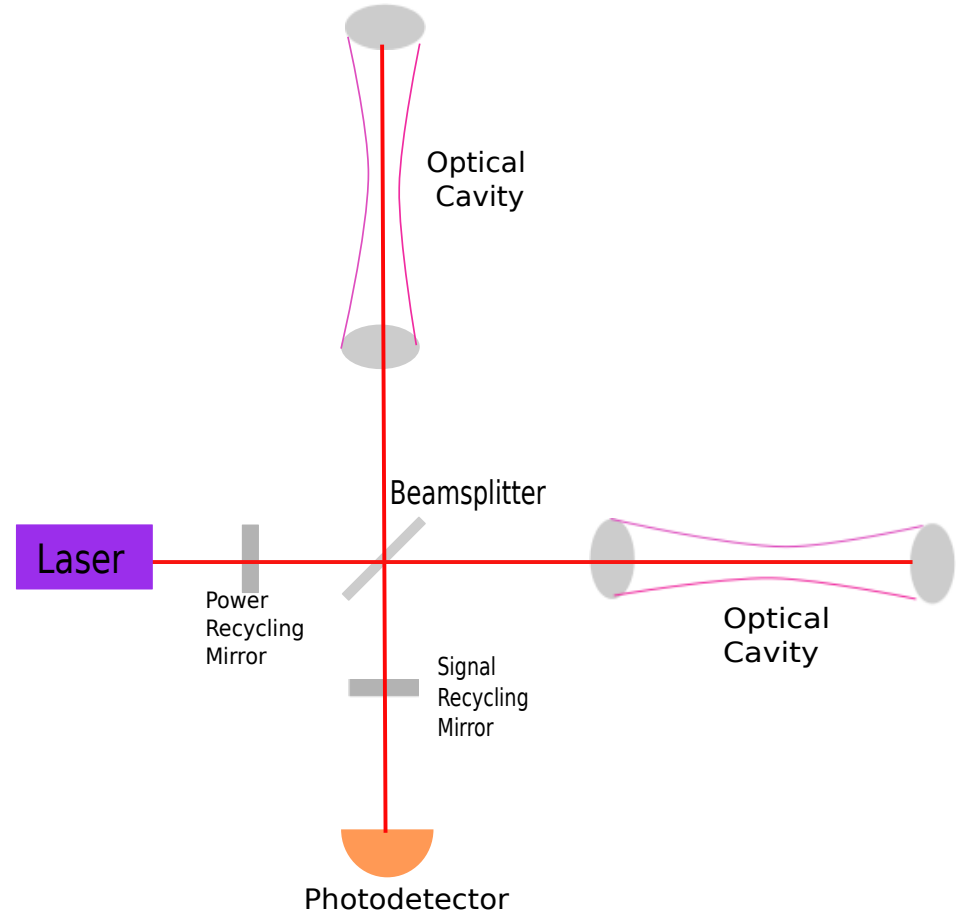


Outline

- Background/Motivation
- Thermal Noise
- Fluctuation Dissipation Theorem
- Pound-Drever-Hall Locking
- Coating Thermal Noise Experiment
- Work Completed
- Conclusions/Future Work

Background/Motivation

- LIGO is a signal and power recycling Michelson interferometer with Fabry-Pérot arms
- Since the strain of a gravitational wave is weak, high precision is needed for detection
- Some limiting sources of noise are: Thermal noise, seismic noise and shot noise





Thermal Noise

- Brownian Noise: Mechanical displacement from thermal fluctuations in dielectric coatings
 - Thermo-optic Noise: Statistical fluctuations of the temperature of a system which are caused by random heat fluxes
1. Thermo-elastic Noise: Changes in the linear expansion coefficient cause surface displacement
 2. Thermo-refractive Noise: Changes in refractive index from temperature fluctuations

Fluctuation Dissipation Theorem

- Callen and Welton's FDT relies on the assumption that the response of a system in thermodynamic equilibrium to small forces being applied is analogous to the response of a system to random fluctuations

$$S_x(f) = \frac{k_B T}{\pi^2 f^2} [Re[Y(f)]]$$

Mechanical admittance



Normal-Mode Decomposition

Compute and sum up
 $[Re[Y(f)]]$
 for each normal-mode

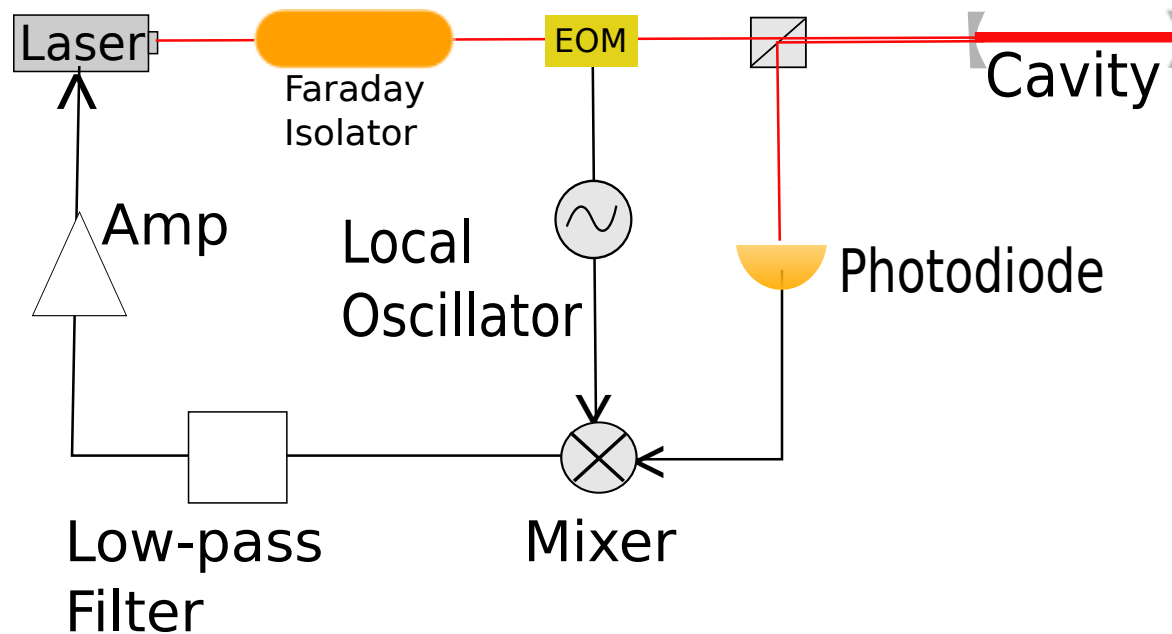


Direct Calculation

$$S_x(f) = \frac{2k_B T}{\pi^2 f^2} \frac{W_{diss}}{F_0^2}$$

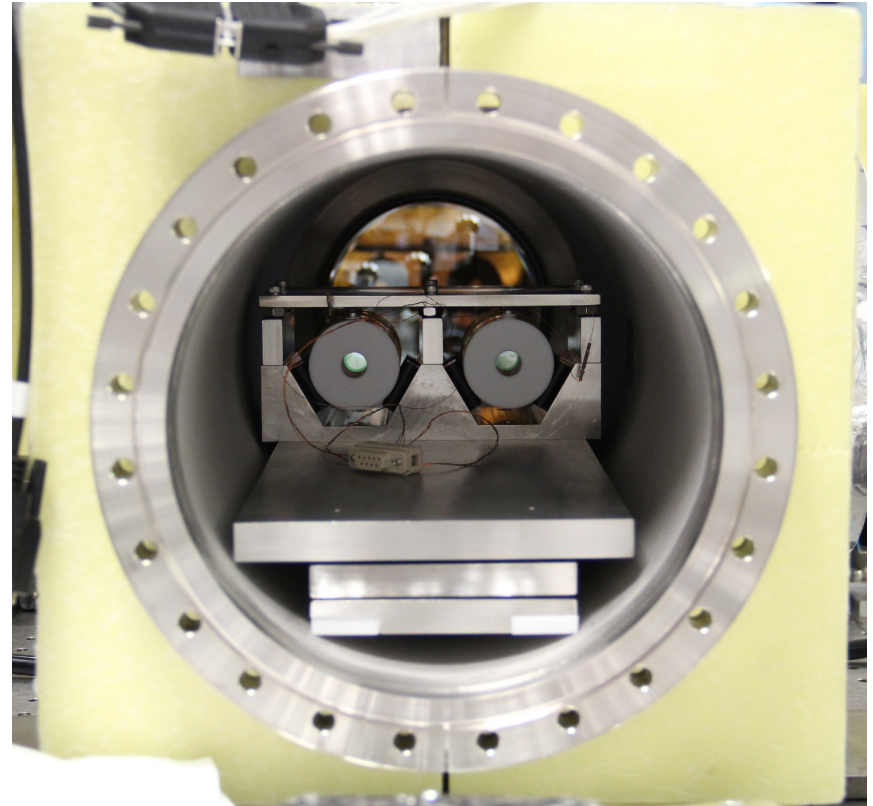
Pound-Drever-Hall Locking

- Frequency locking a laser to a Fabry-Perot cavity that is known to be stable
- Adjust frequency of the laser to match the resonant mode of the cavity



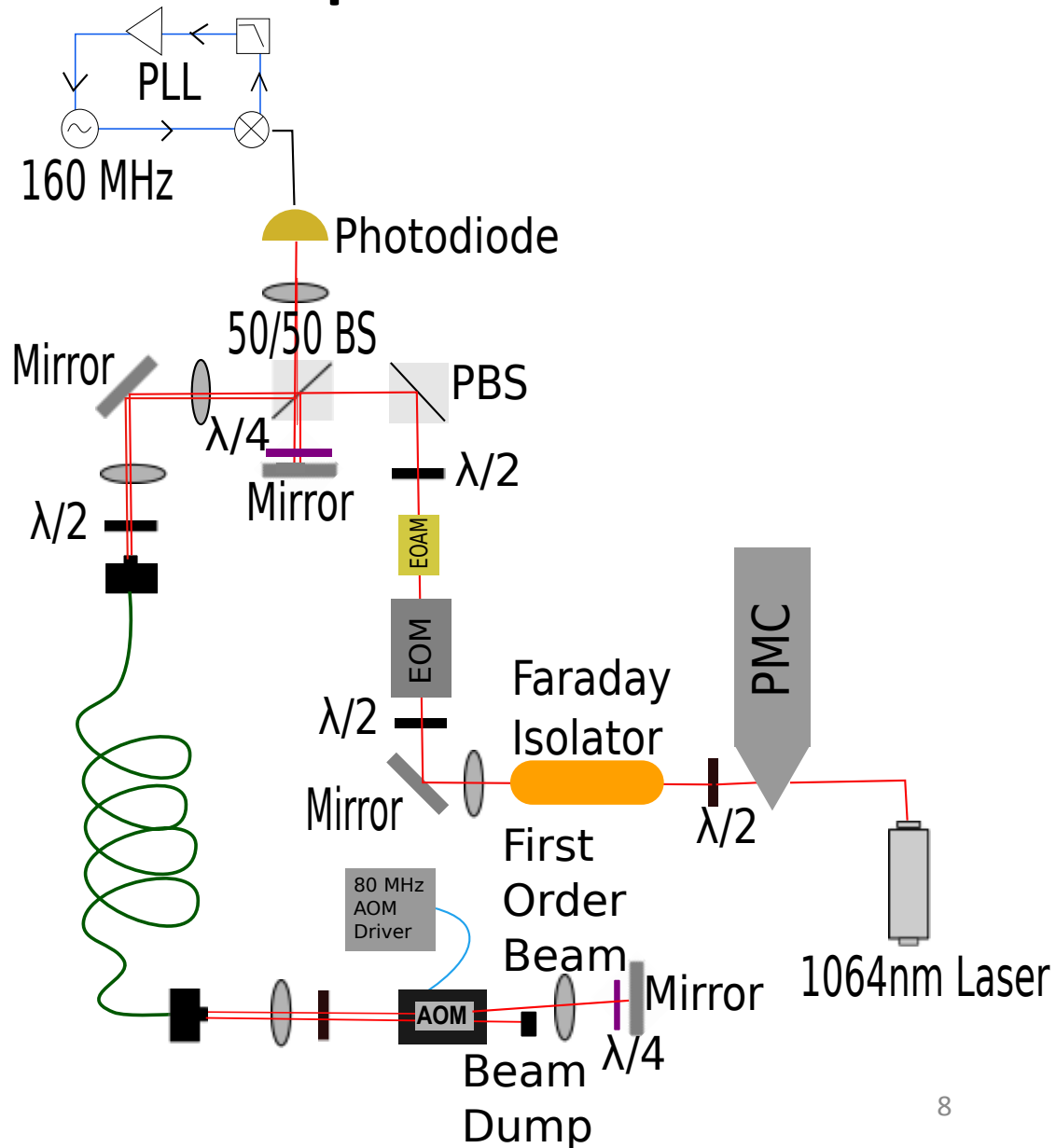
Coating Thermal Noise Experiment

- Two Fabry-Perot cavities with silica tantala mirror coatings are used
- Each cavity has its own stabilized laser, which is locked to the cavities with the PDH technique
- Cavities are kept in a temperature stabilized vacuum chamber
- Pick off light to use as frequency reference

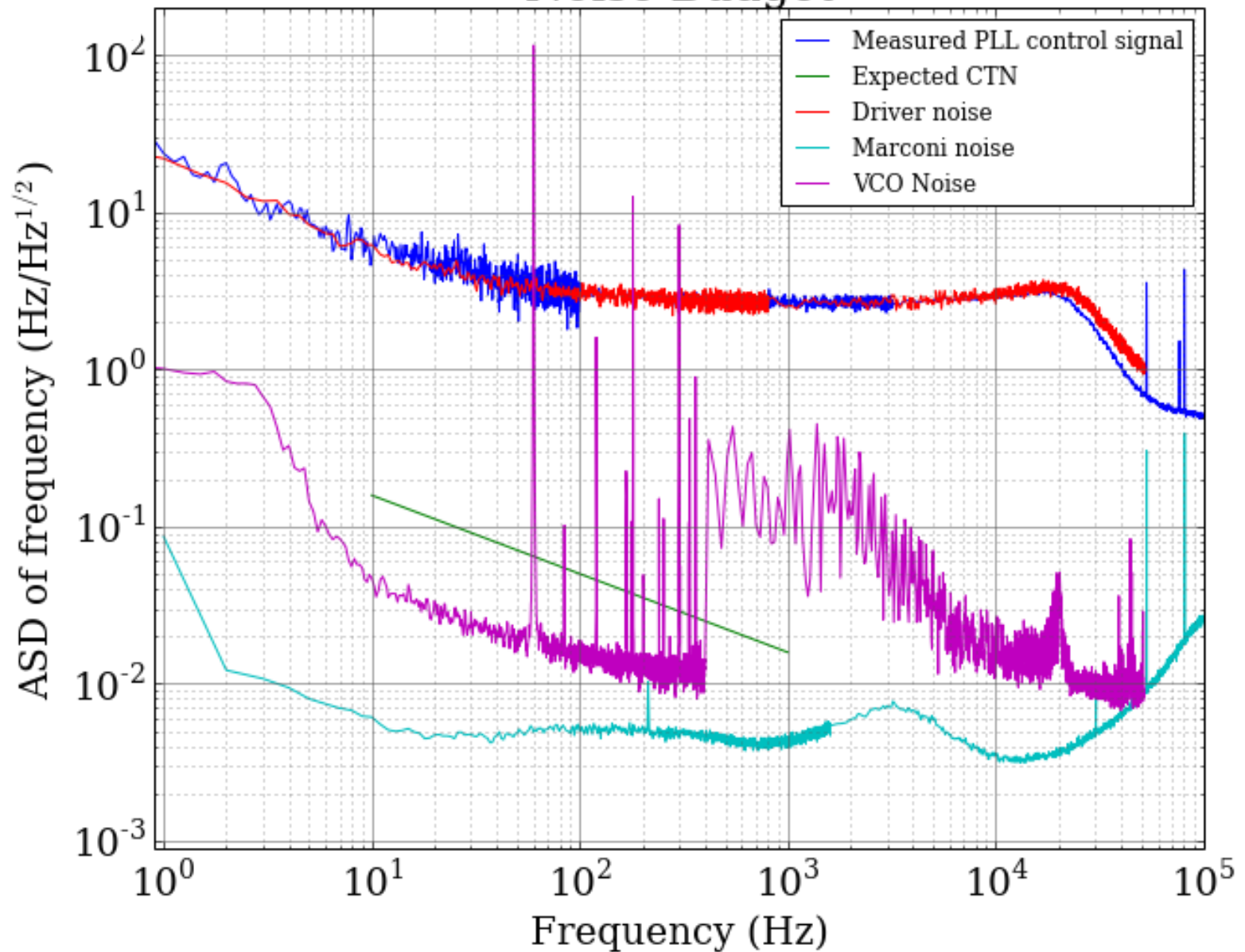


Initial Setup

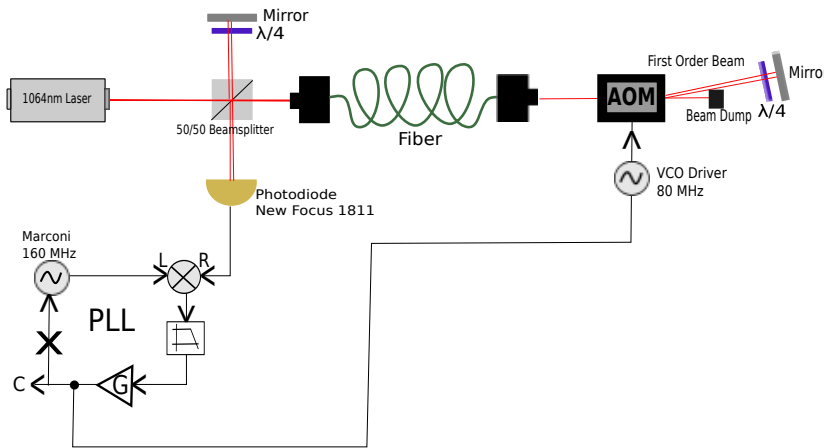
- Mode-Matched into the fiber
- Double passed through AOM
- Look at beat frequency
- Measure PLL control signal



Noise Budget



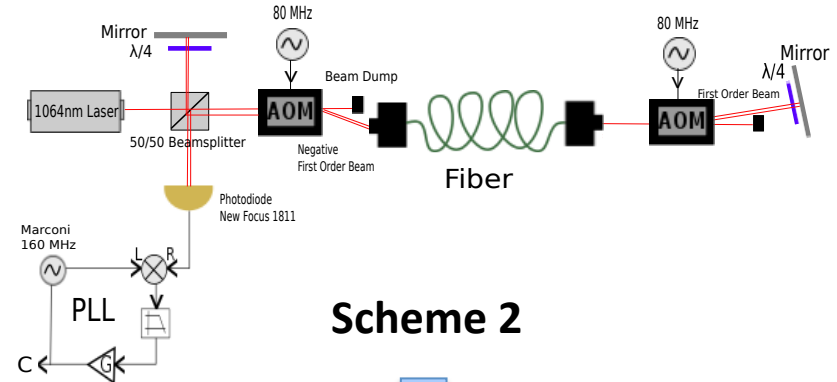
Noise Cancellation



Scheme 1



- Uses 1 AOM
- Lock Optical Beat to Marconi to stabilize light



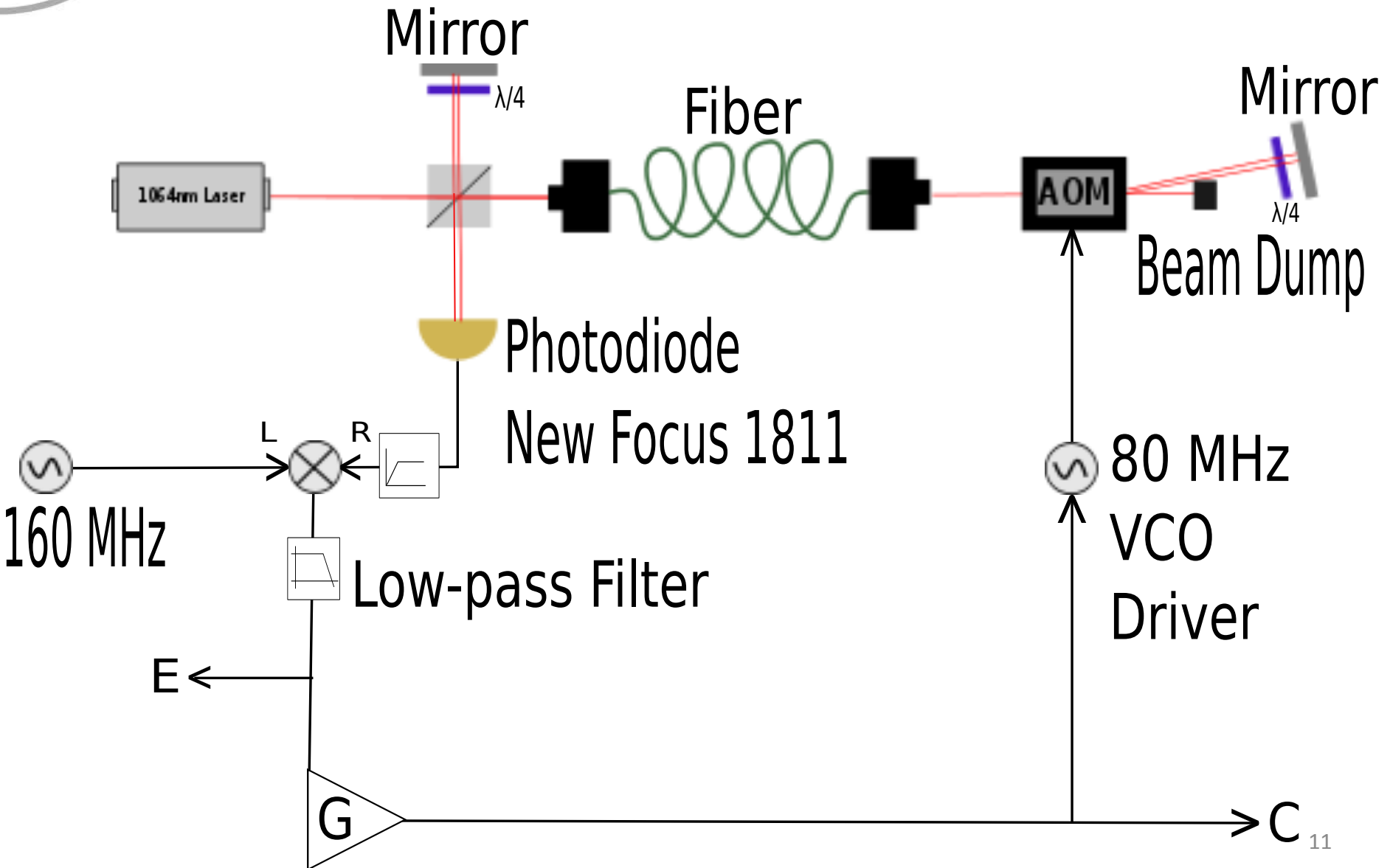
Scheme 2



- Uses 2 AOMs
- Has been demonstrated before
- Inject negative first order beam into fiber input, second AOM is modulated such that the first order beam emerges and is double passed back through the fiber

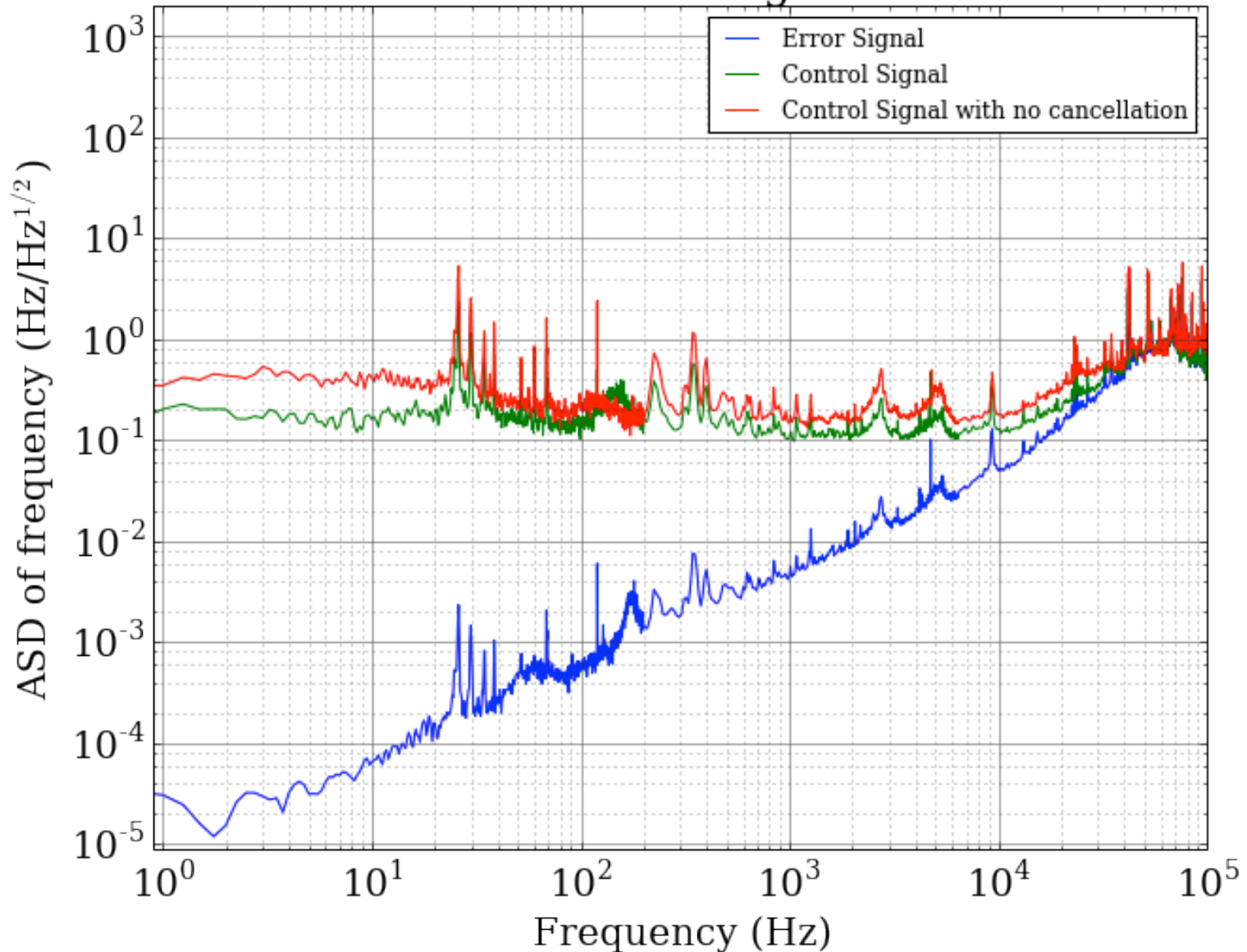
LIGO

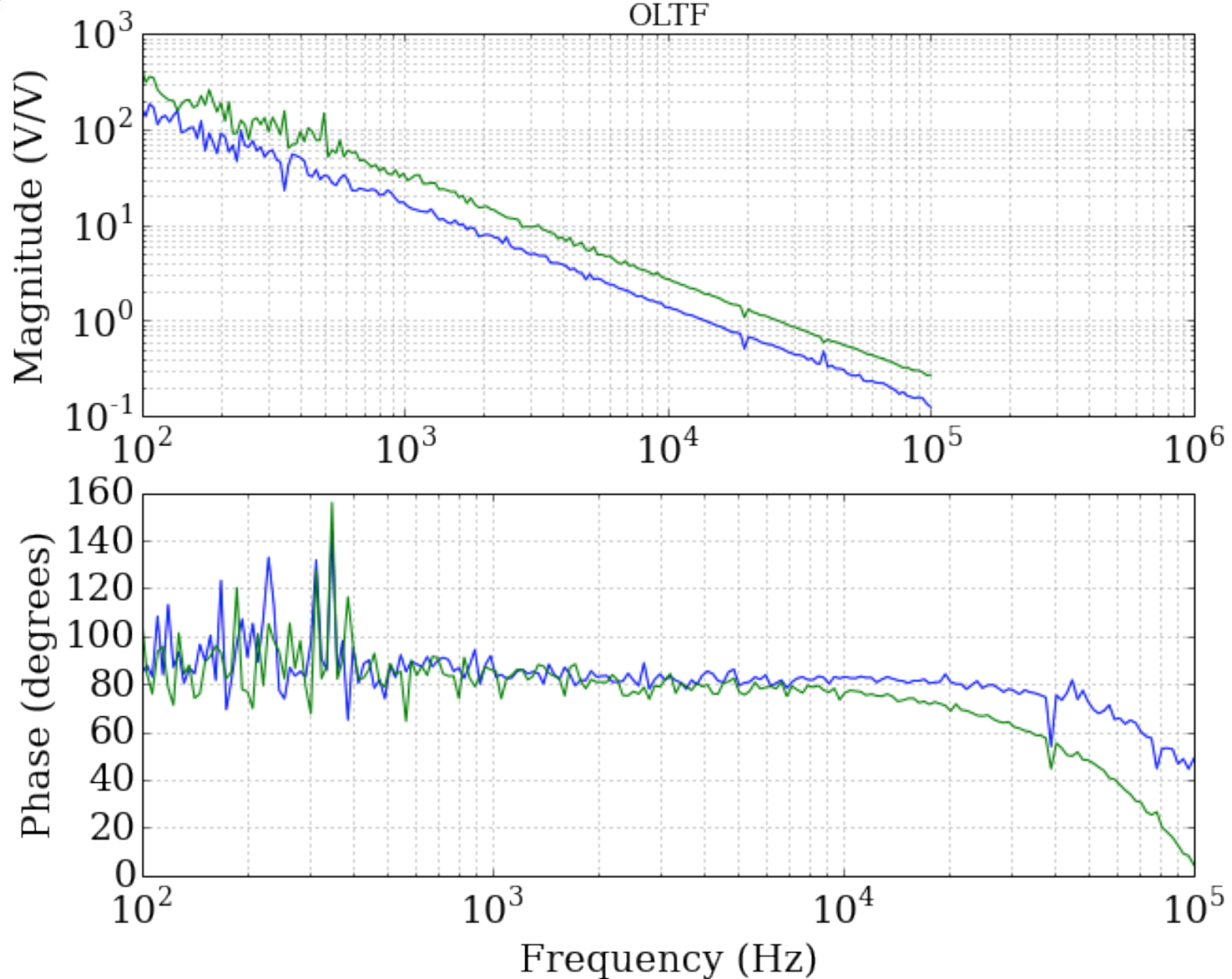
New Setup



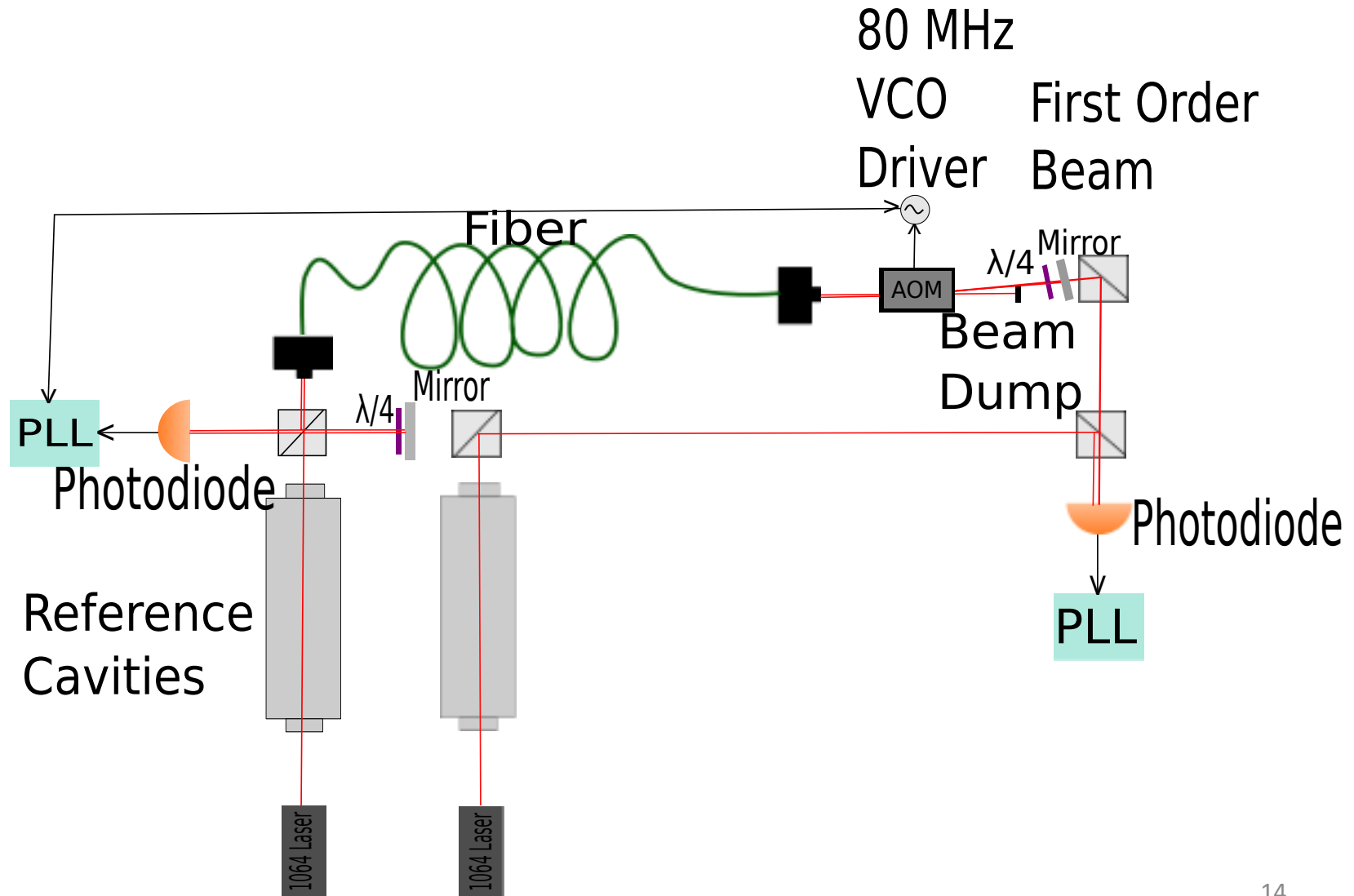
Results

Noise Budget

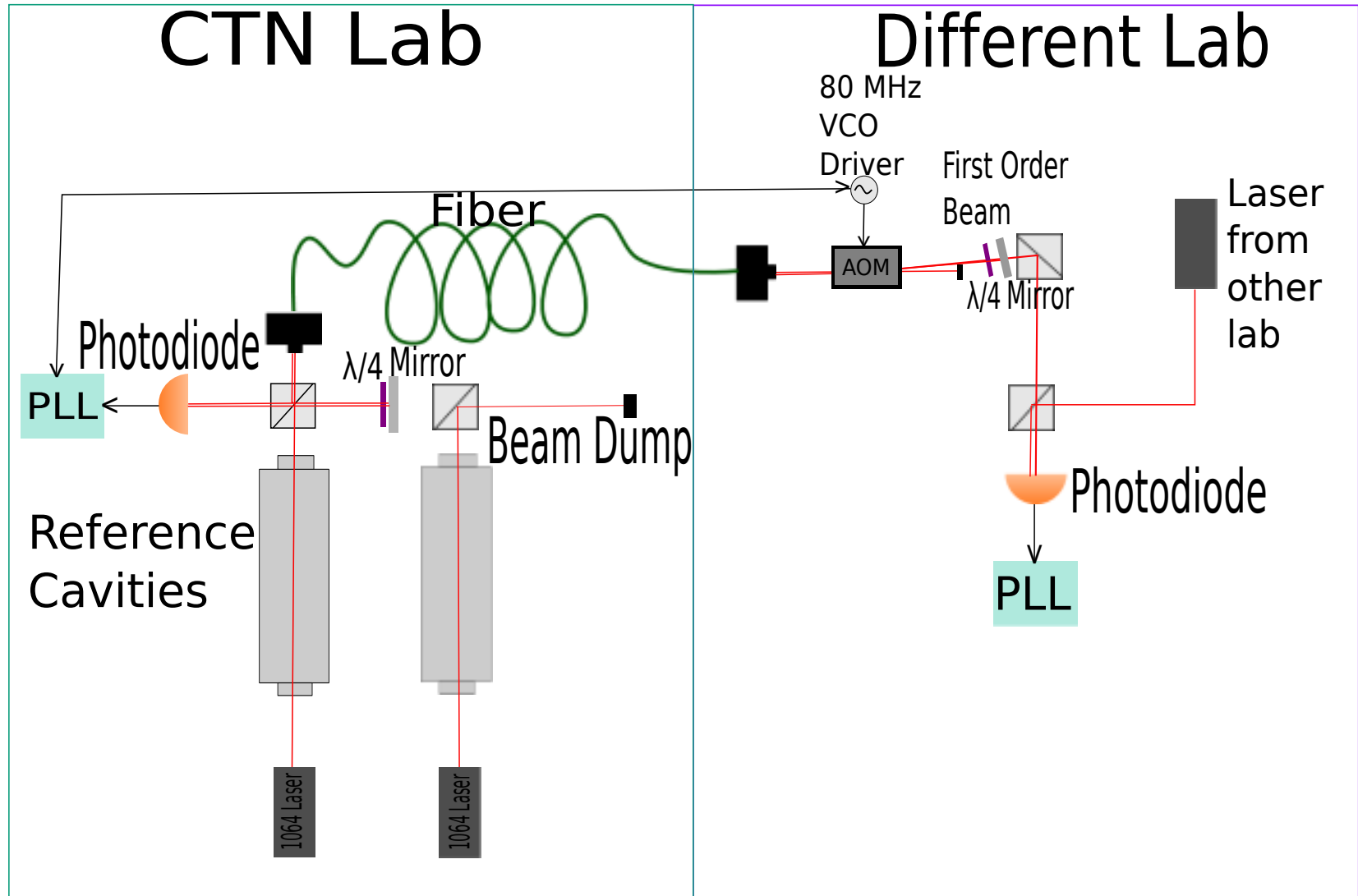




Conclusions/Future Work



LIGO Conclusions/Future Work



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Thank you!!

