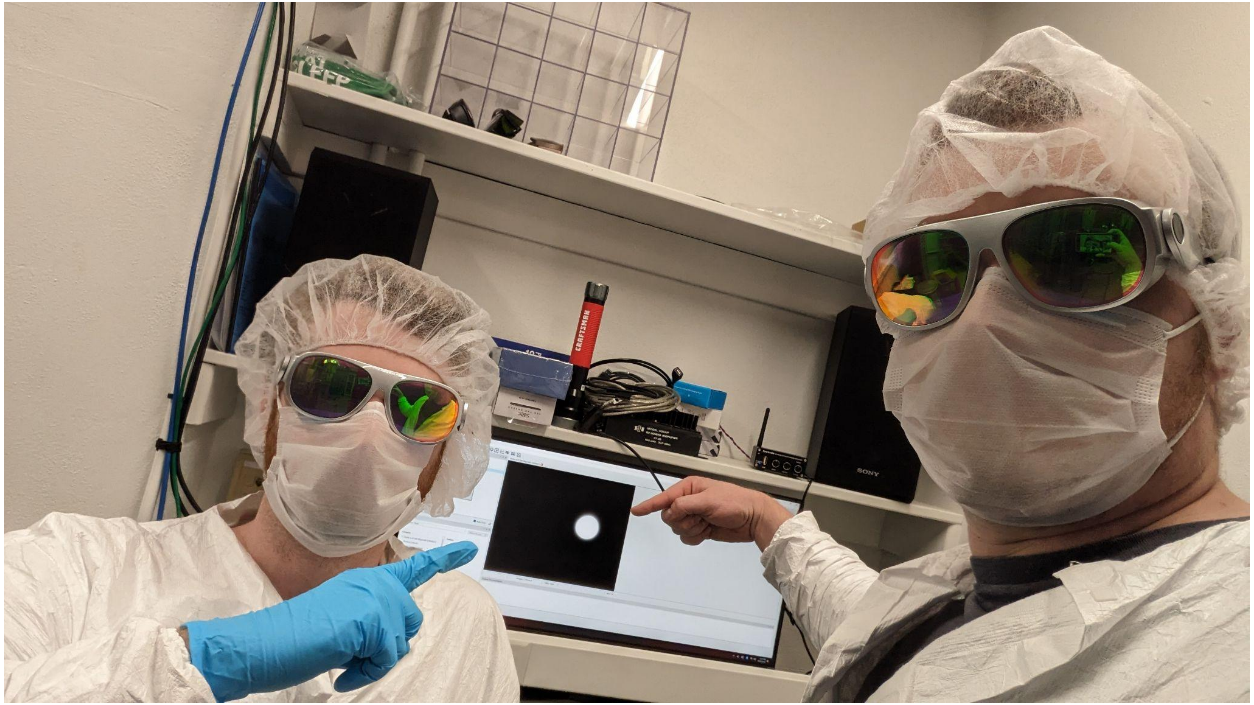
Transition slide

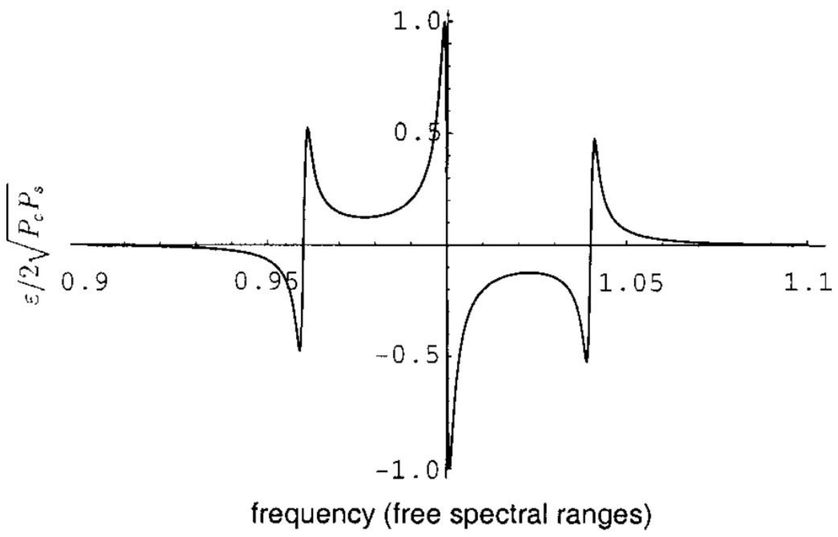
Cavity control

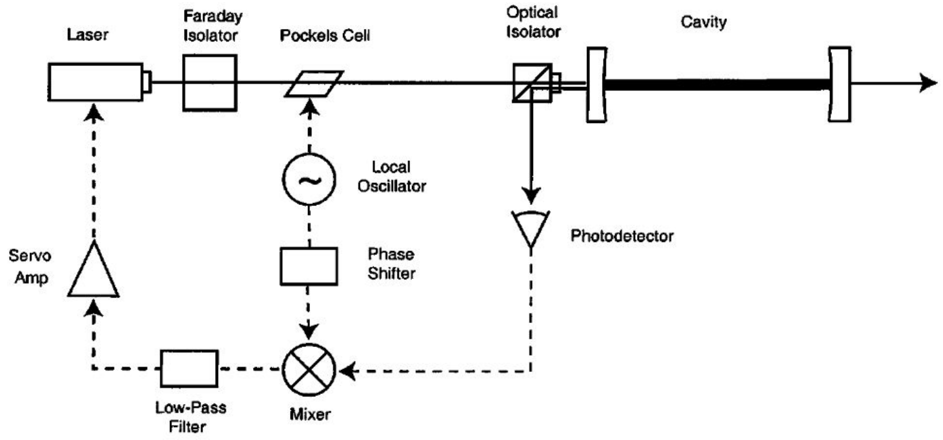


Review of PDH sensing

The Pound-Drever Hall technique adds sidebands to the laser to measure the frequency offset between a laser and a cavity

PDH error signal

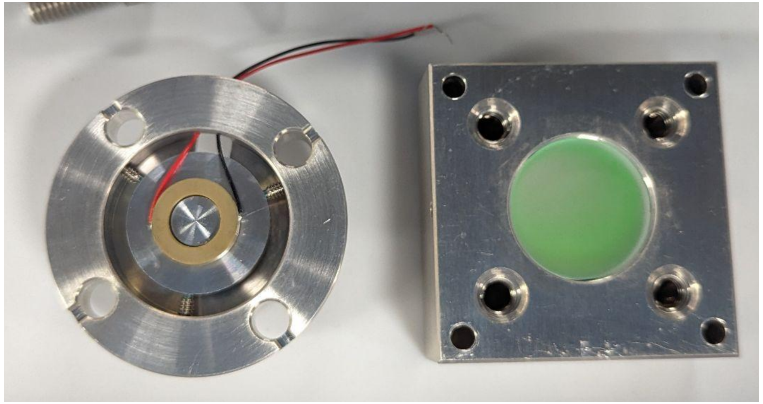


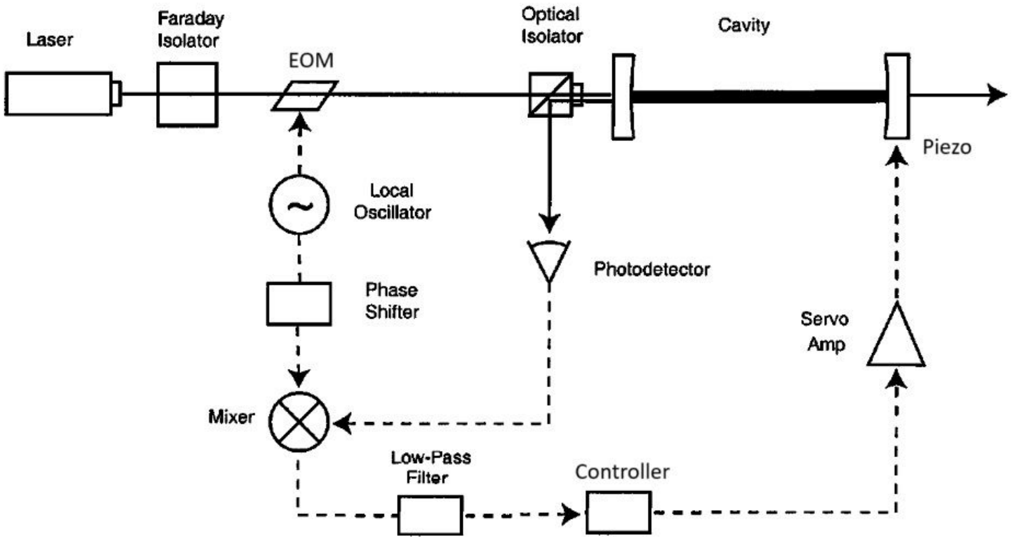


Eric D. Black - An introduction to Pound–Drever–Hall laser frequency stabilization

Piezo actuation

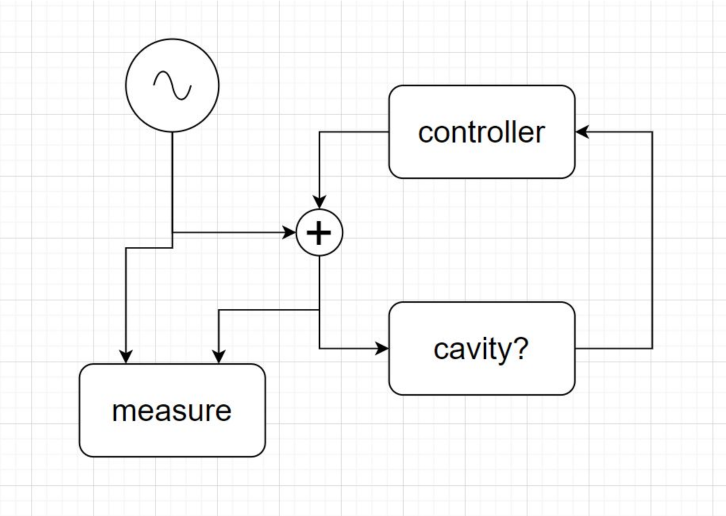
-To match the frequency of 4 cavities to 1 laser, we must control the cavity lengths rather than the laser frequency

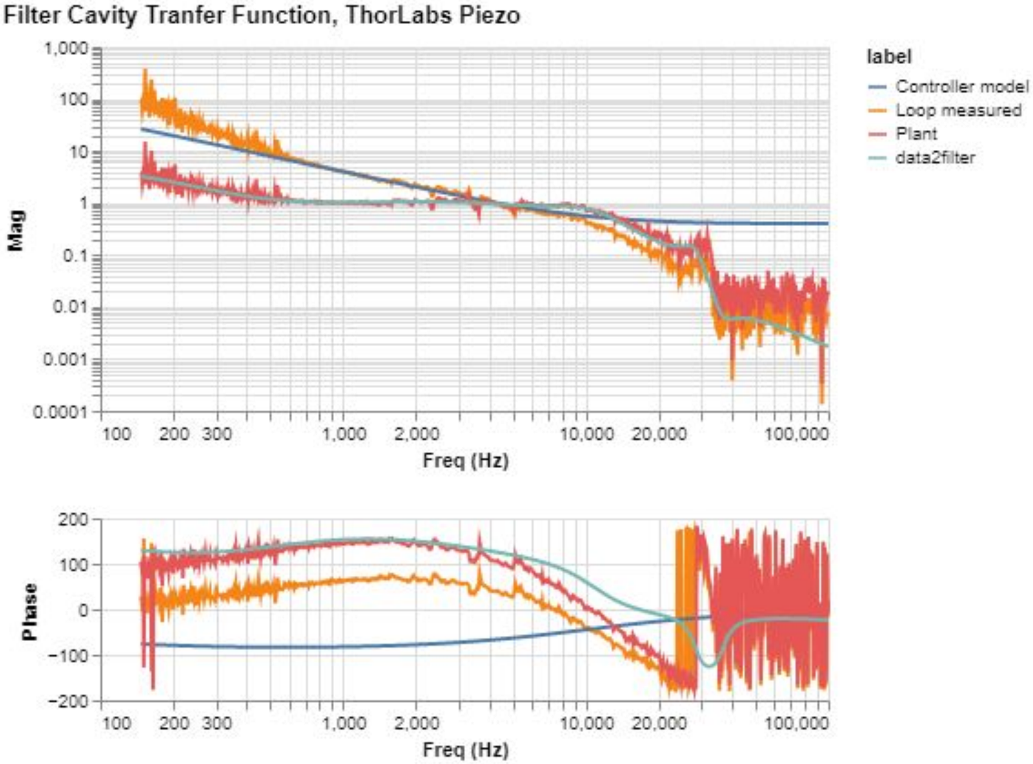




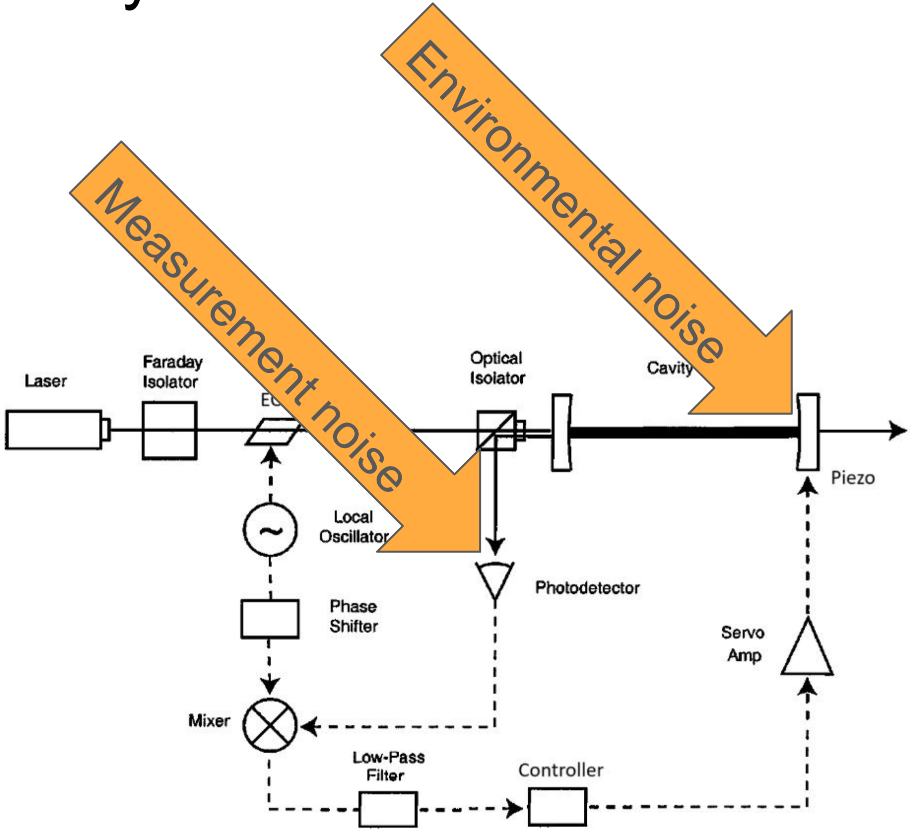
System identification of a Cavity

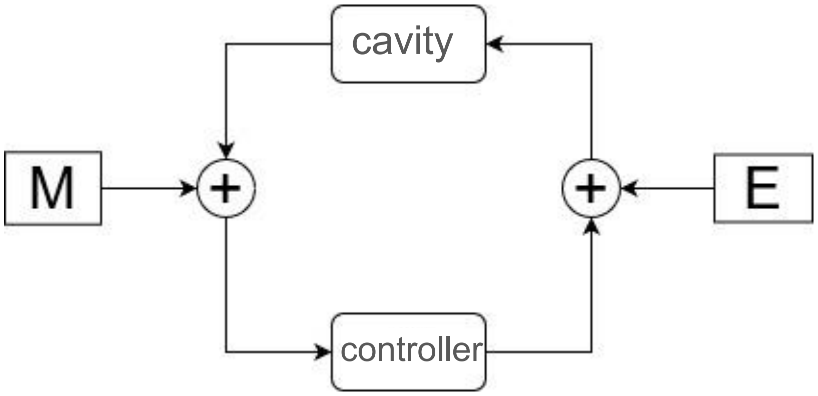
A swept sin is injected to drive the piezo and the response of the error signal is measured.





Full system model and noise sources

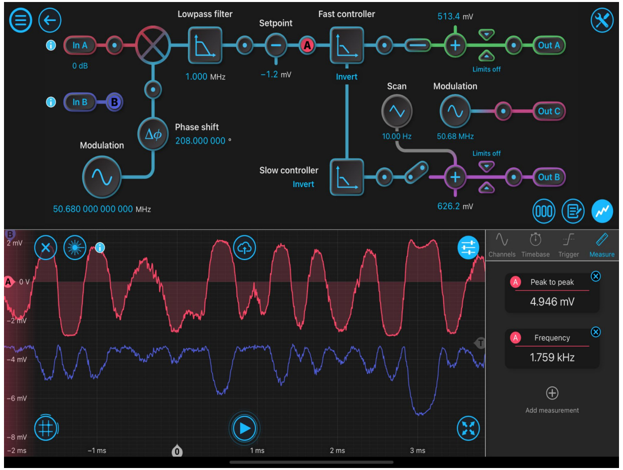




Controller synthesis

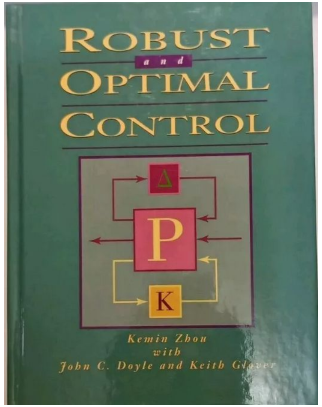
Analog PID

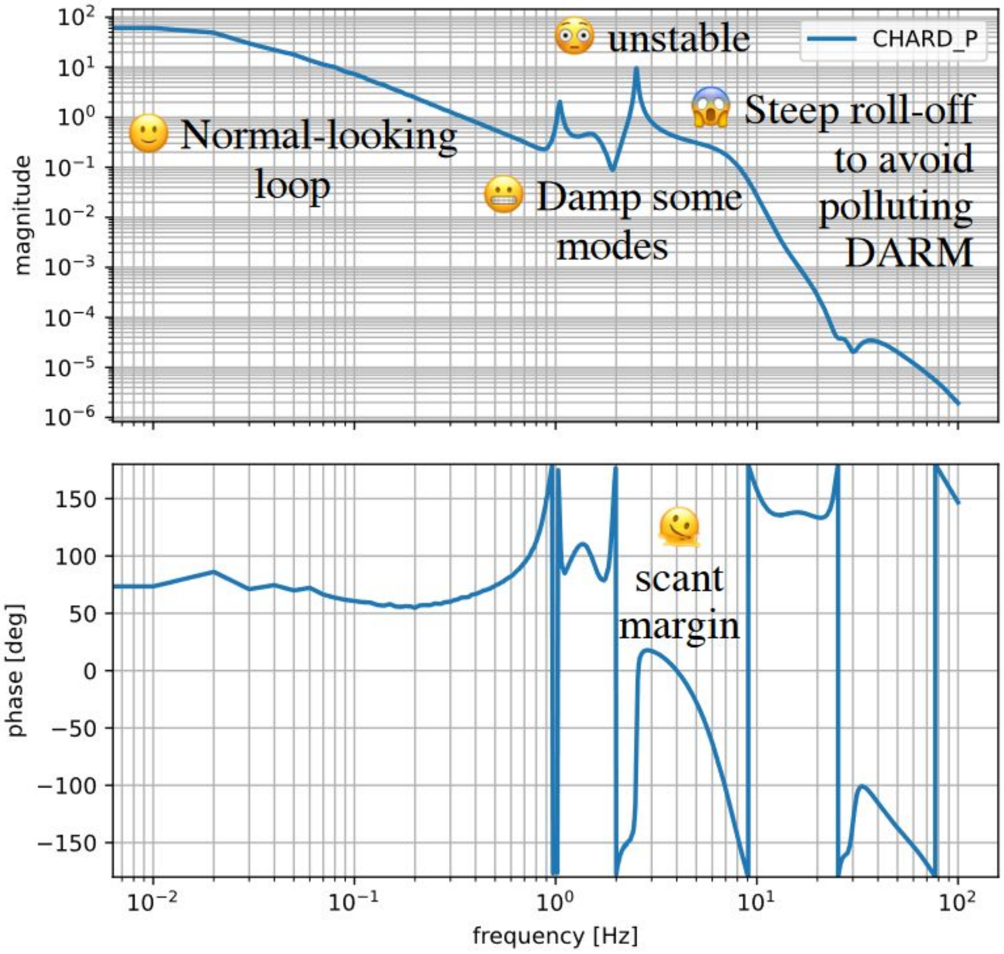
Digital PID - Moku laser lock box



Controller Synthesis

- increased performance from high order controllers designed with love
- robust and optimal control theory can automate this design





Controller design: GQuEST specifications

GQuEST

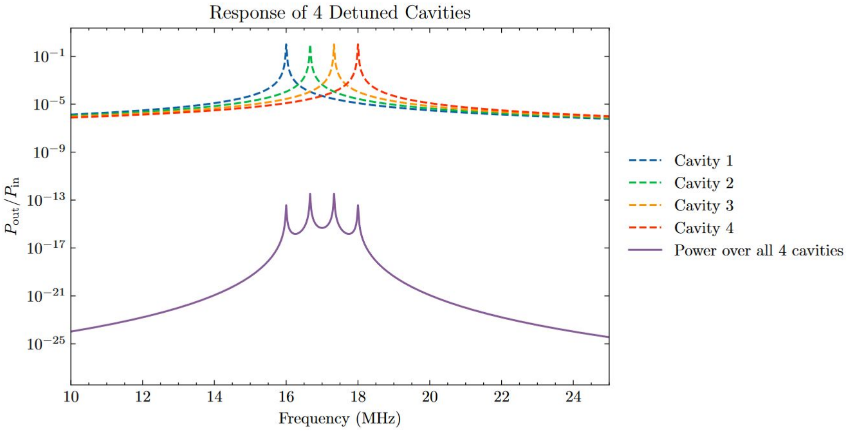
- alignment of all 4 cavities to within a fraction of their bandwidth
- seismic noise, acoustic noise
- laser frequency noise

Controller

- noise rejection
- open loop unity gain frequency

Hardware

- sample rate
- input to output delay
- digital quantization noise
- filter complexity



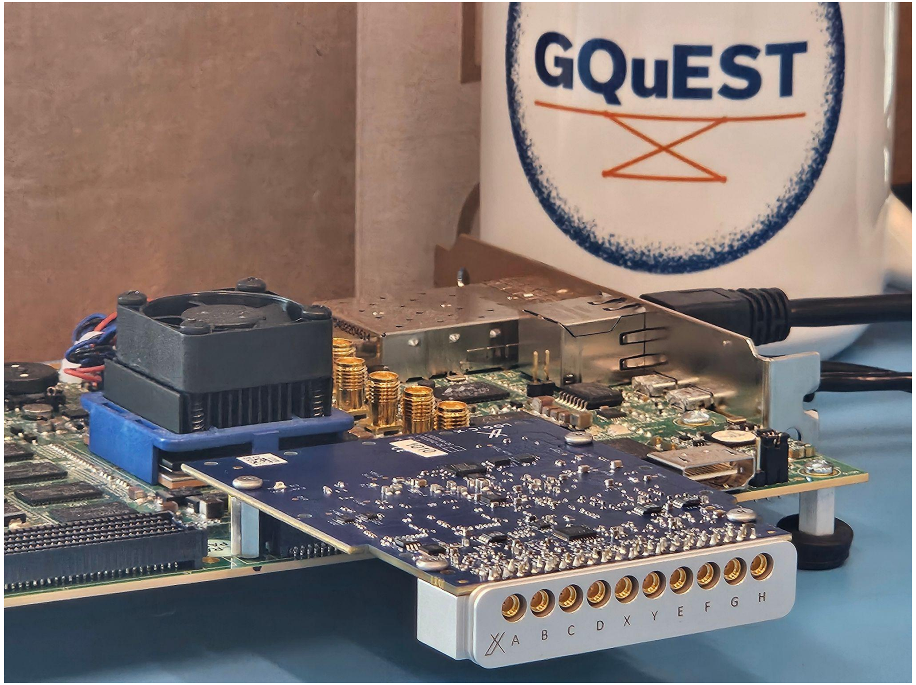
Controller implementation - FPGA

Digital implementation is flexible

FPGAs are fast (high sample rate, low delay)

Developed by Chris Stoughton and Javier Contreras

Fermilab



AMD/Xilinx Artix 7 FPGA with Logic-X ADC/DAC board

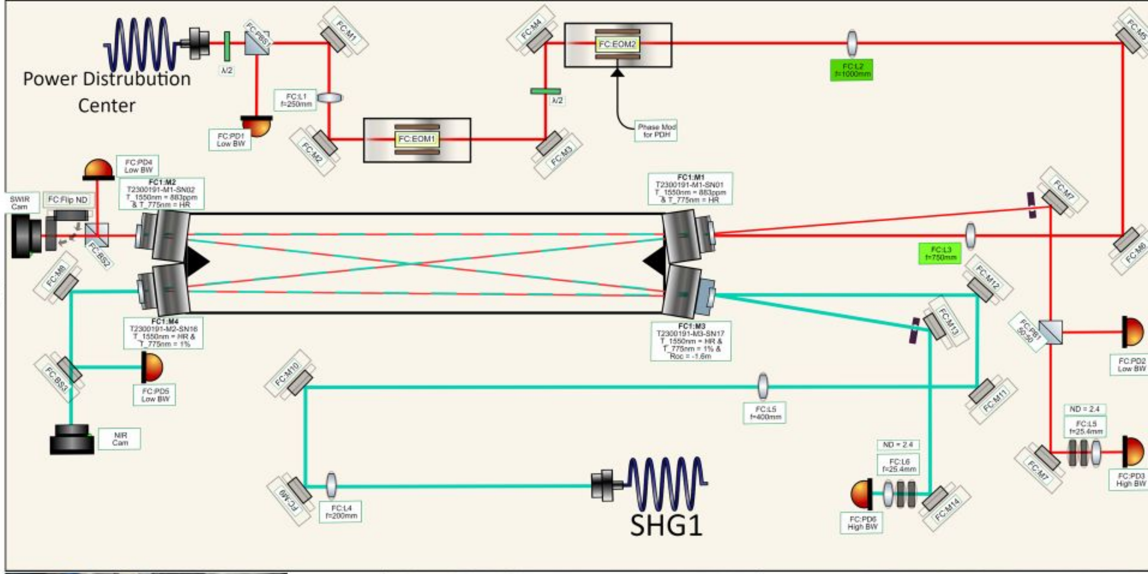
TRANSITION SLIDE

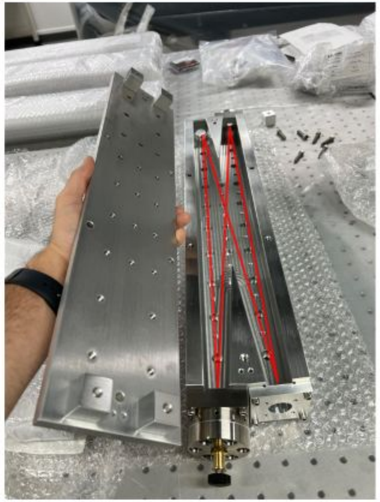
What do we need to make this happen?

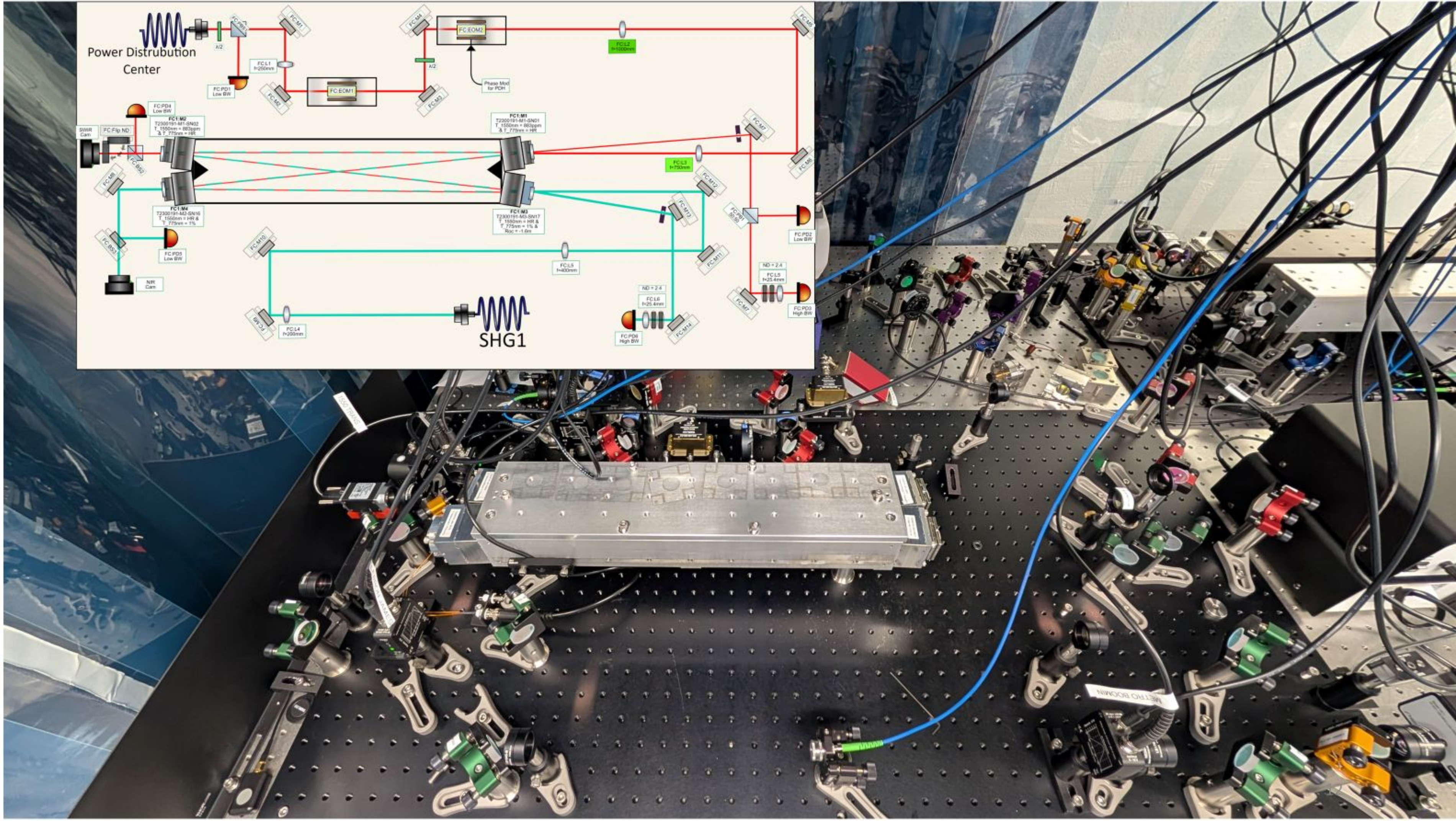
- What we need:
  - 4 cavities in series, >3000 F, 20 kHz BW.
  - Needs to pass the signal photons (on a common resonance).
  - Would like to avoid cavities in vacuum if possible.
  - >20 orders of carrier suppression.
- Challenges:
  - Control while in air.
  - Signal has almost no power (so how do we control the cavities).
  - High throughput (need low loss)/mechanical resonances/other experimental challenges.
- How do we prove this scheme will work?

Current Layout in the Lab

- Bowtie cavity configuration. Cavity itself is a solid machined piece of metal.
- Cavity optics are mounted on Newport Flexture mounts.
- 6 orders of magnitude carrier suppression each – 4 cavities total
- 2.4m optical path length
- 42 kHz pass bandwidth
- Design finesse 3300
- Locking scheme is to use 775 nm light detuned at $\epsilon_{\rm r} = 17.6\ \mathrm{MHz}$ using AOMs to shift and EOMs for PDH.
- PDH actuation on piezo mirrors. Mirrors are not glued but compressed in place with viton and SM1 rings.
- Begun diagnostics and characterizations of the cavities.





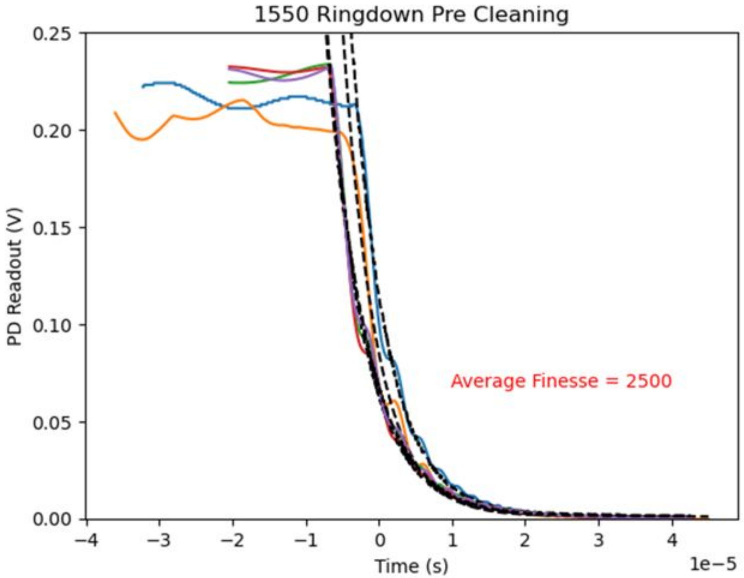


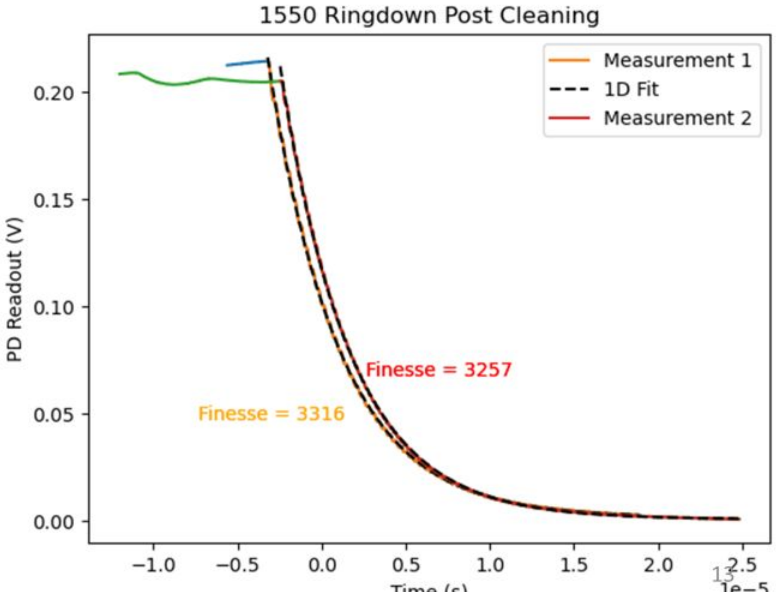
Power Distrubution Center
λ/2
FC:PBS
FC:M1
FC:L1 f=250mm
FC:PD1 Low BW
FC:M2
FC:EOM1
FC:M3
FC:M4
λ/2
FC:EOM2
Phase Mod for PDH
FC:L2 f=1000mm
FC:M5
FC:PD4 Low BW
SWIR Cam
FC:Flip ND
FC:BS2
FC1:M2 T2300191-M1-SN02 T_1550nm = 883ppm & T_775nm = HR
FC1:M1 T2300191-M1-SN01 T_1550nm = 883ppm & T_775nm = HR
FC:M7
FC:L3 f=750mm
FC:M6
FC:M8
FC1:M4 T2300191-M2-SN16 T_1550nm = HR & T_775nm = 1%
FC1:M3 T2300191-M3-SN17 T_1550nm = HR & T_775nm = 1% & Roc = -1.6m
FC:M12
FC:M13
FC:PB1 50:50
FC:PD2 Low BW
FC:BS1
FC:PD5 Low BW
FC:M10
FC:L5 f=400mm
FC:M11
NIR Cam
ND = 2.4
FC:L6 f=25.4mm
ND = 2.4
FC:L5 f=25.4mm
FC:M7
FC:PD3 High BW
FC:M9
FC:L4 f=200mm
SHG1
FC:PD6 High BW
FC:M14

Initial Measurements - Finesse

Initial measurement of F =2500. Suspicion of optics just being dirty (Company: FiveNine Optics). Applied first contact to cavity mirrors and recovered alignment. Finesse now close to spec.

$$\tau_{\text{storage}} = \frac{2\mathscr{L}_{\text{cavity}}\mathscr{F}}{\pi c} = \frac{\mathscr{F}}{\pi f_{\text{FSR}}}$$



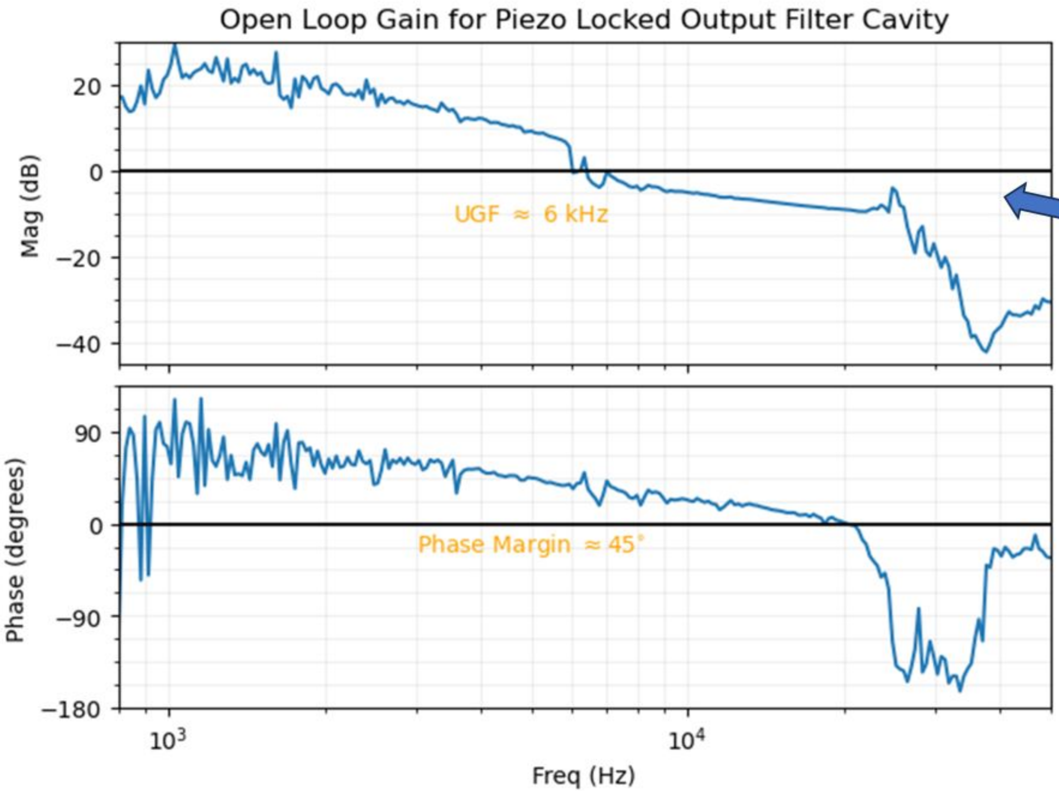


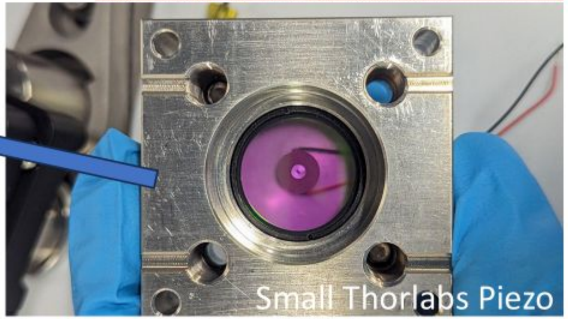
Initial Measurements – Power Suppression Single Cavity

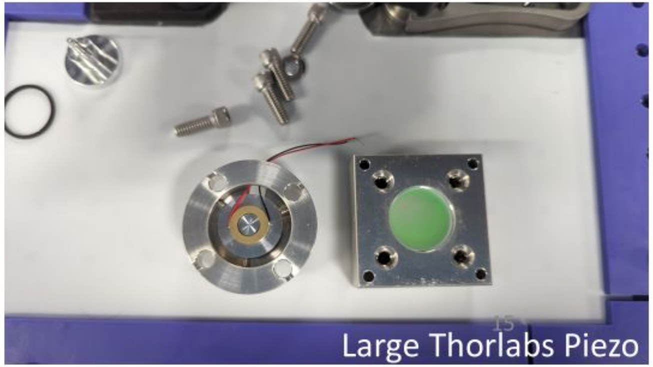
- Process:
  1) Lock Cavity on 775 nm light.
  2) Shift AOM frequency so that 1550 nm and 775 nm light are coresonant.
  3) Measure 1550 nm power when coresonant and minimally coresonant.
  4) $> 3 * 10^5$ suppression of 0,0 (performed before cleaning the optics)

Scan using laser over full a FSR

Initial Measurements - Cavity Control with Piezo

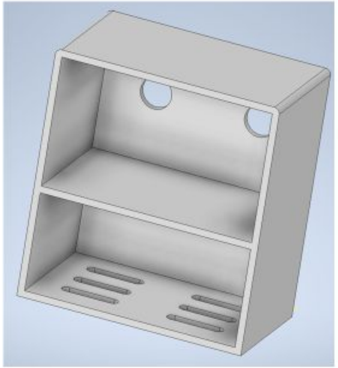


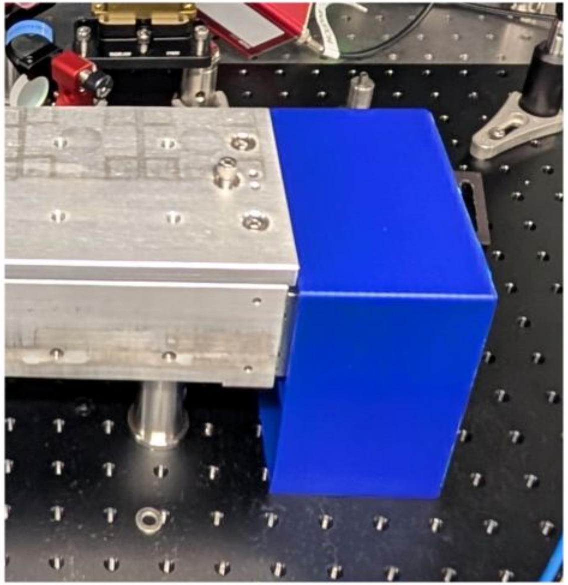




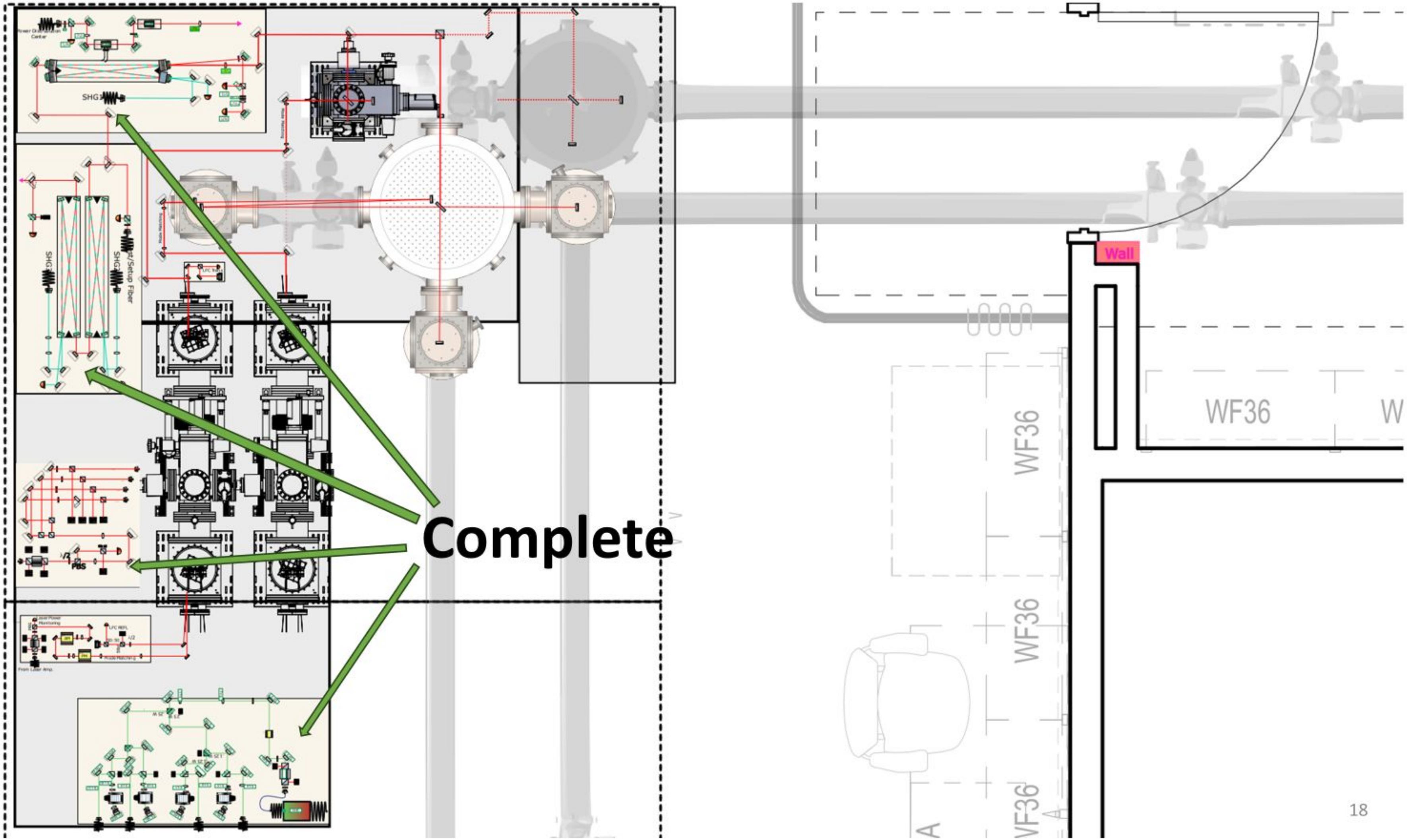
Addressing in-air Cavities

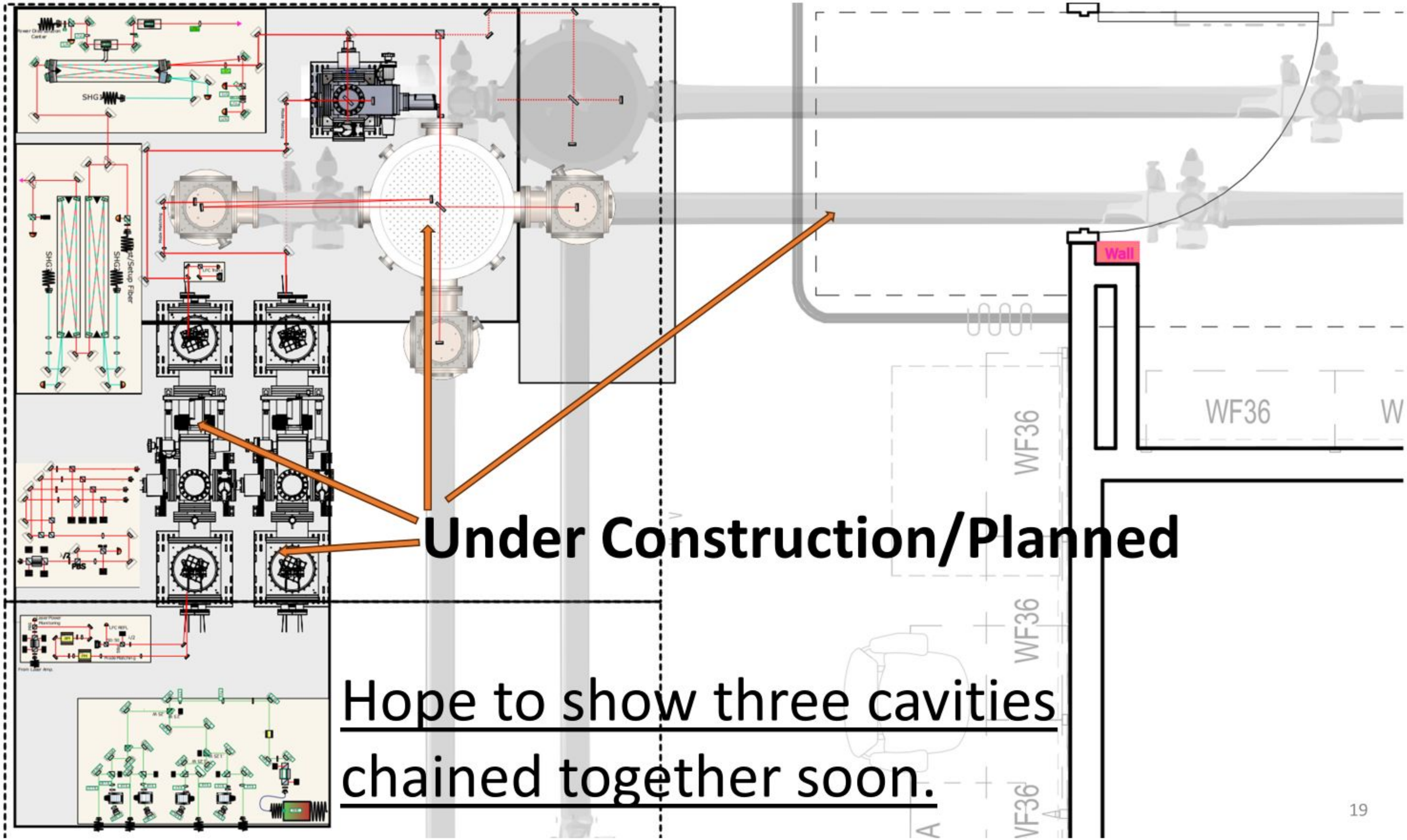
- Initial design for cavity “earmuffs”. Sound coupling at the ends.
- Prototype of the shell, plans to add metal exterior/some kind of damper inside.
- Also have plans with the LIGO Lab at Caltech to test an in-vacuum cavity.





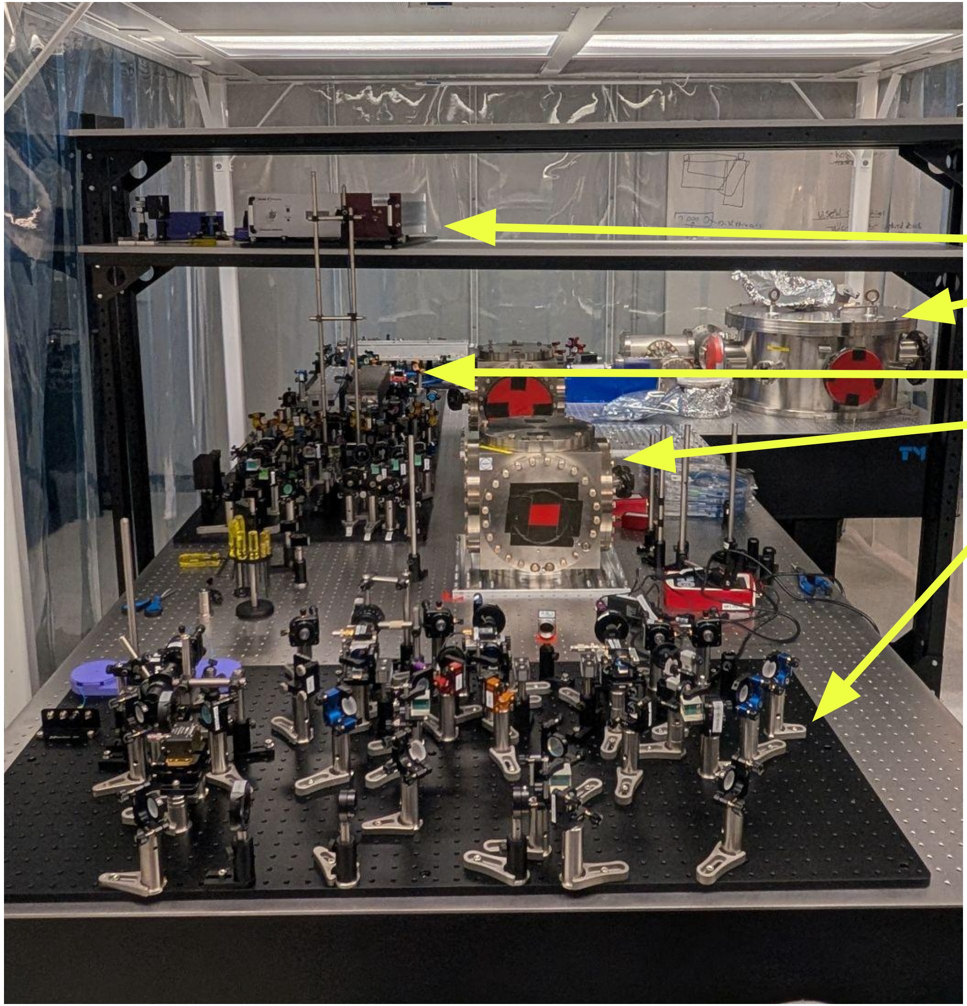
Mr. Brightside


Complete
Wall
WF36
WF36
WF36
SHG
PBS



Under Construction/Planned

Hope to show three cavities chained together soon.



- Seed Laser and Amplifier
- Central Vessel - Holds main beamsplitter for IFO
- Output Filter Cavities
- Laser Filter Cavity
- SHG and AOM sled