LIGO – What goes into a GW detector

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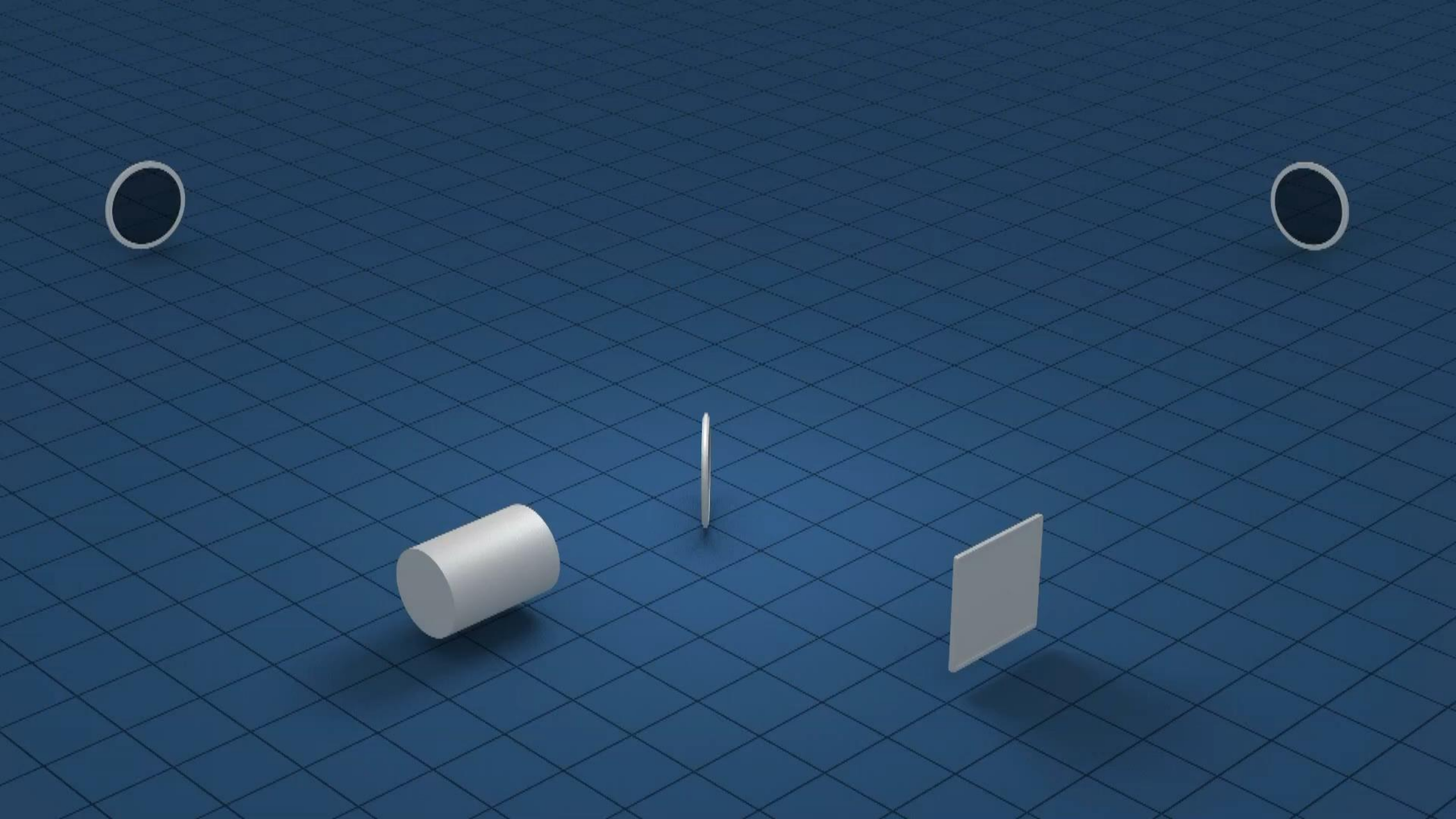
DCC: LIGO-G2501210-v3

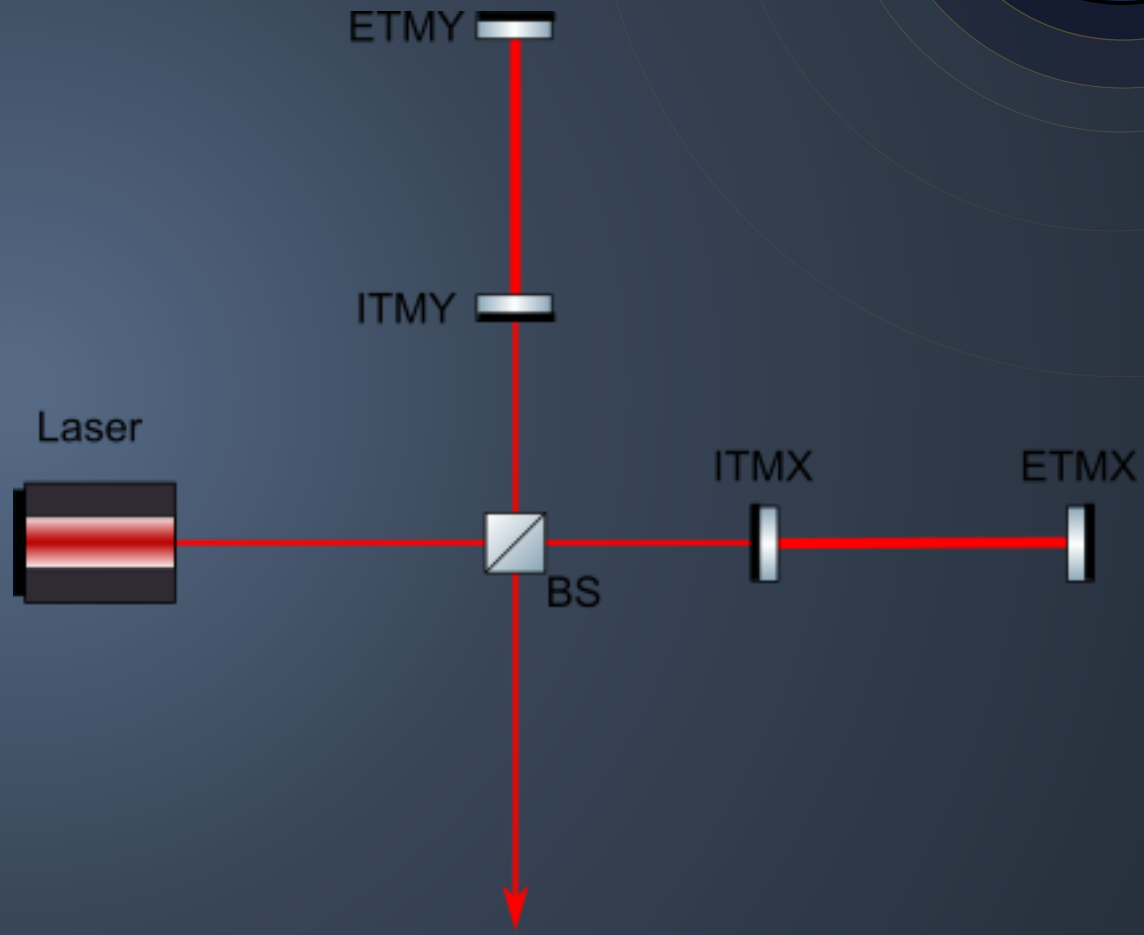
Optical Systems



Add Arm Cavities

Increase light travel time

- Mirrors added are called ‘input test masses’.
  - Create resonant optical cavities.
  - Light trapped between two mirrors.
  - Equivalent to making arms longer -> smaller strain detectable.

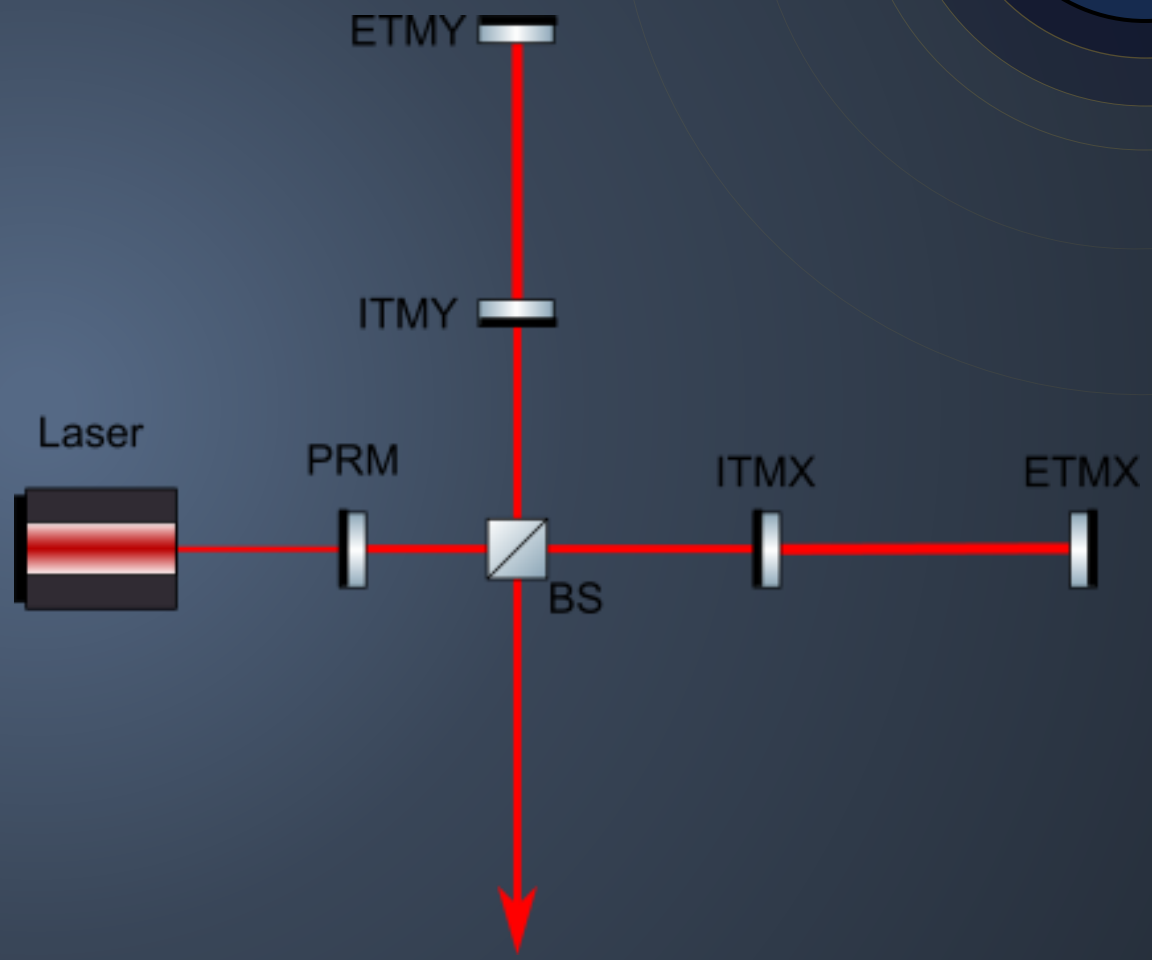


Simplified Michelson with Arm Cavities

Add Arm Cavities

Increase input power

- Quantum Shot Noise
  - SNR = $\sqrt{n}$
  - More photons, higher SNR
- Technical limits to laser power.
- Add mirror between ITMs and Laser.
  - Light builds up to higher power inside interferometer.



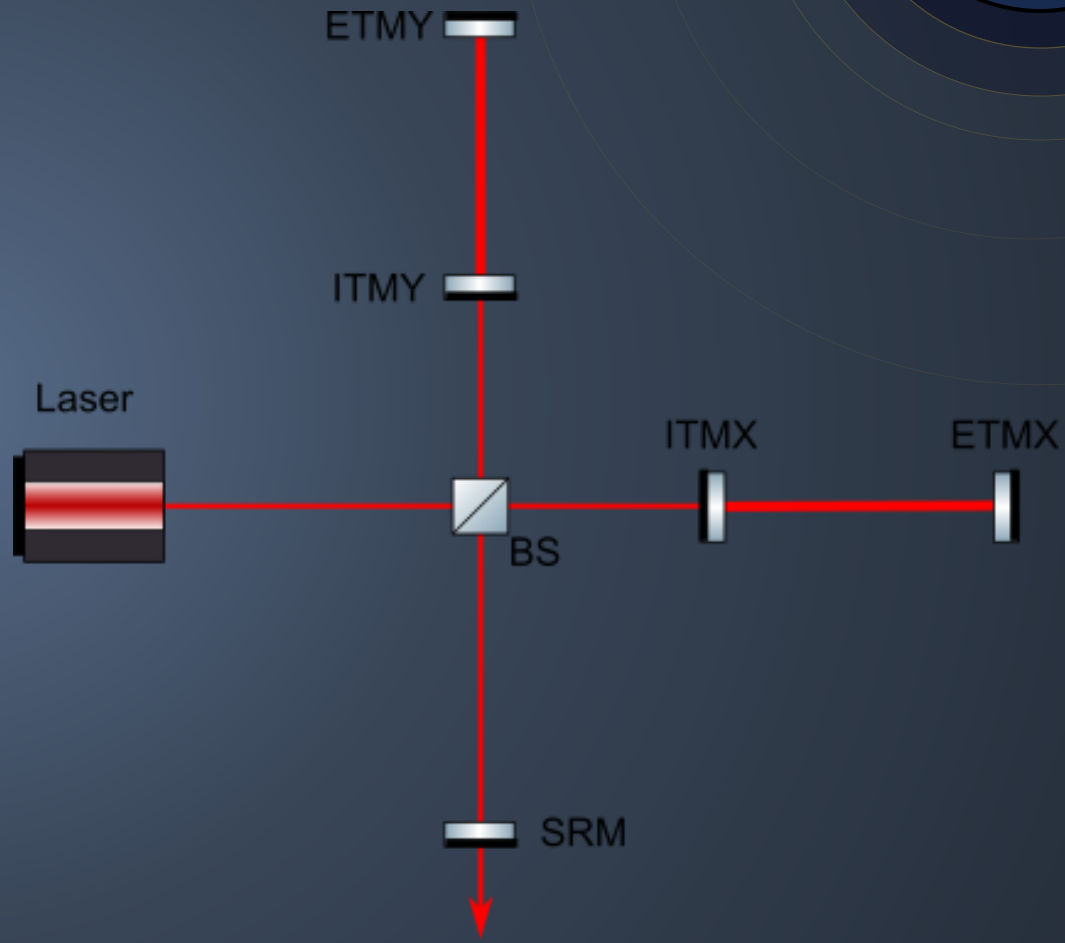
Power Recycled Michelson

Add Signal Extraction

Extracts GW signal

- Original beam circulates back into interferometer but signal is extracted from IFO.
- Broadens frequency sensitivity of IFO.

Adds mirror before output.



Dual-Recycled Michelson

Mechanical Systems

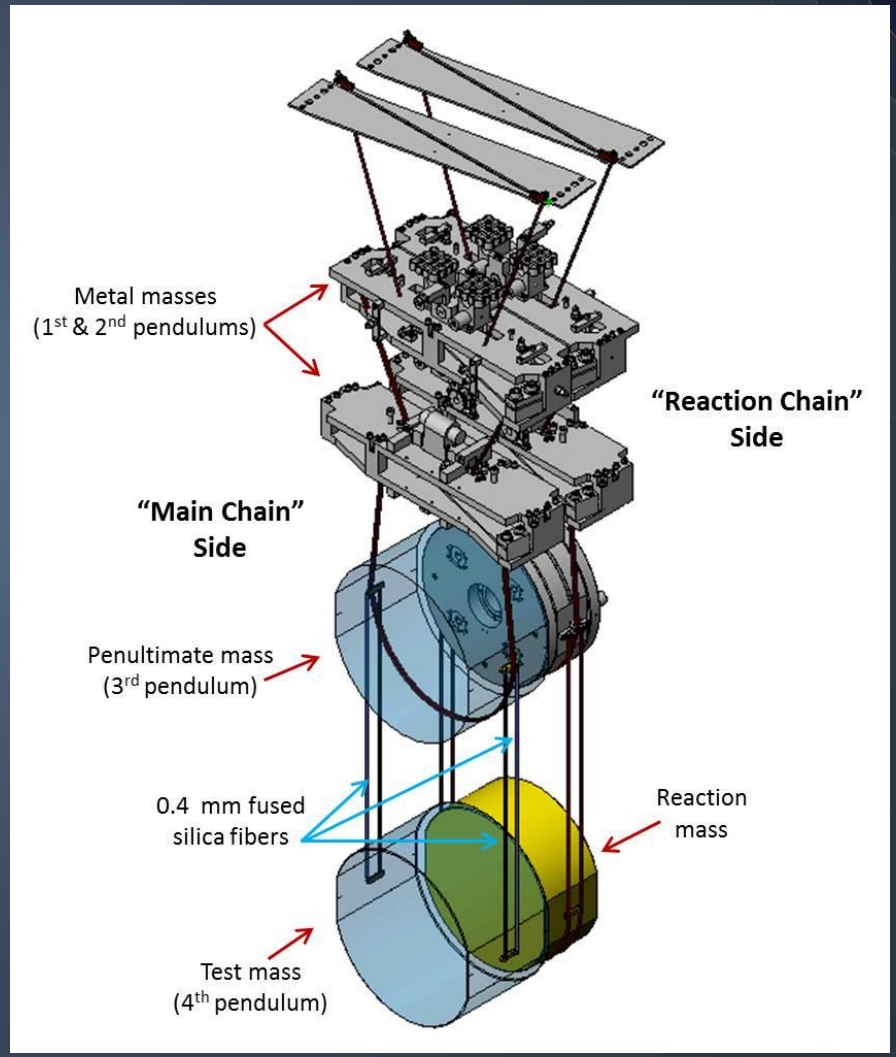
Suspensions

End mirrors must be in free-fall

- Can achieve in horizontal direction.
- Use Mirror Suspensions.
- Provide isolation above resonance.

Cascaded Suspension stages

- Give extra noise filtering above resonance.



Credit: IGR, University of Glasgow / LIGO Lab

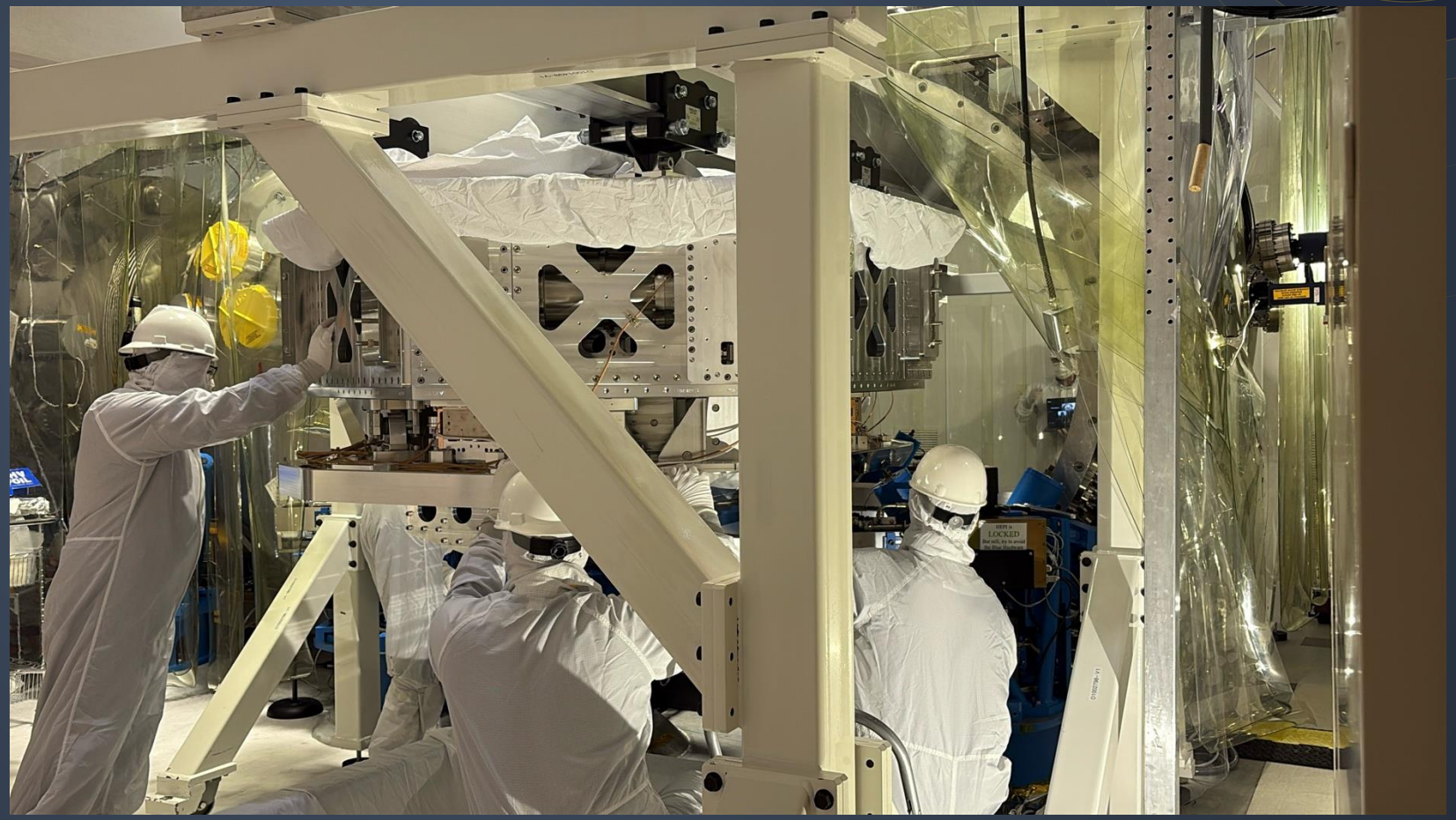
Seismic Isolation

Ground Motion

- Earthquakes.
- Wind.
- Waves.
- Traffic.

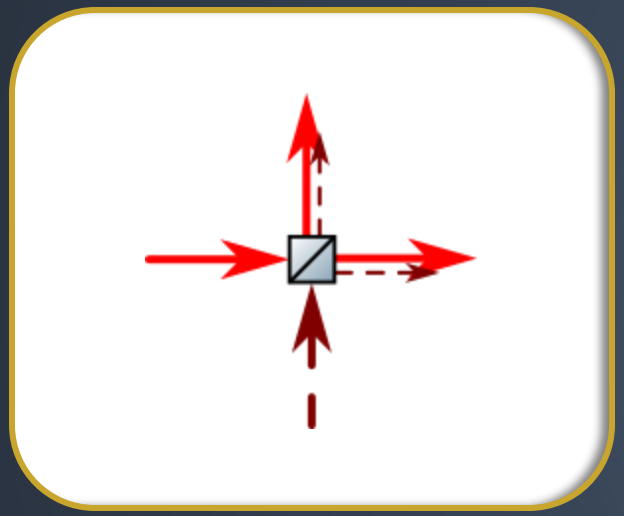
Seismic Isolation Tables

- Uses position and inertial sensors.
- Feedback & feedforward used to keep table still.



Credit: Betsy Weaver

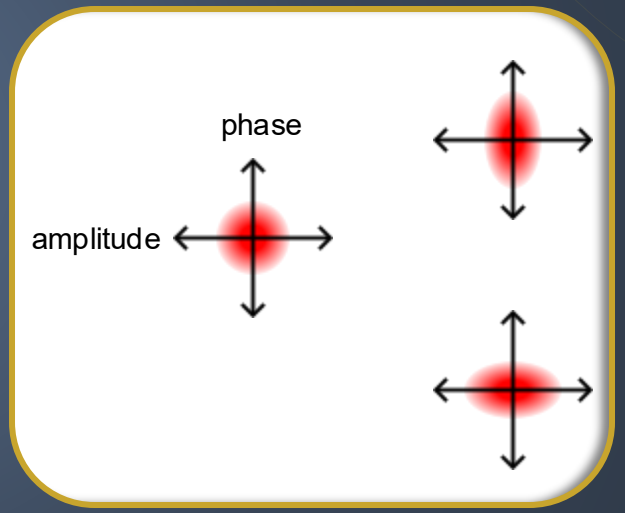
Quantum Noise



Vacuum adds in uncorrelated noise

vacuum noise

Amplitude squeezed vacuum



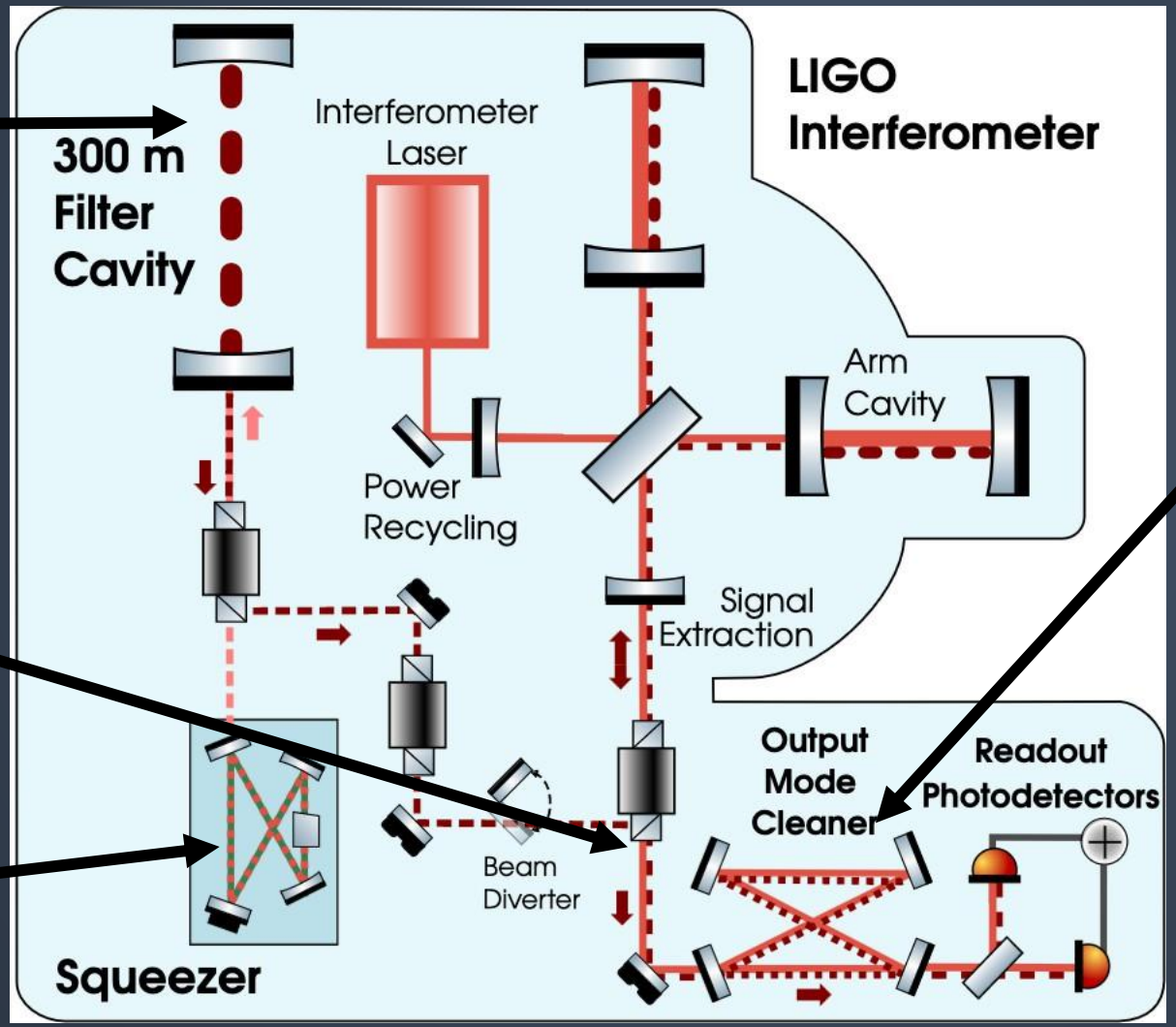
Phase squeezed vacuum

LIGO Squeezer

Makes squeezing ellipse rotate with frequency

Squeezed light injected through dark port

Produces squeezed light using non-linear crystal



Cleans output beam of higher order modes and sidebands

[3] D. Ganapathy et. al. Physical Review X 13, 041021 (2023)

Any Questions?