Observing the dark and violent universe with LIGO

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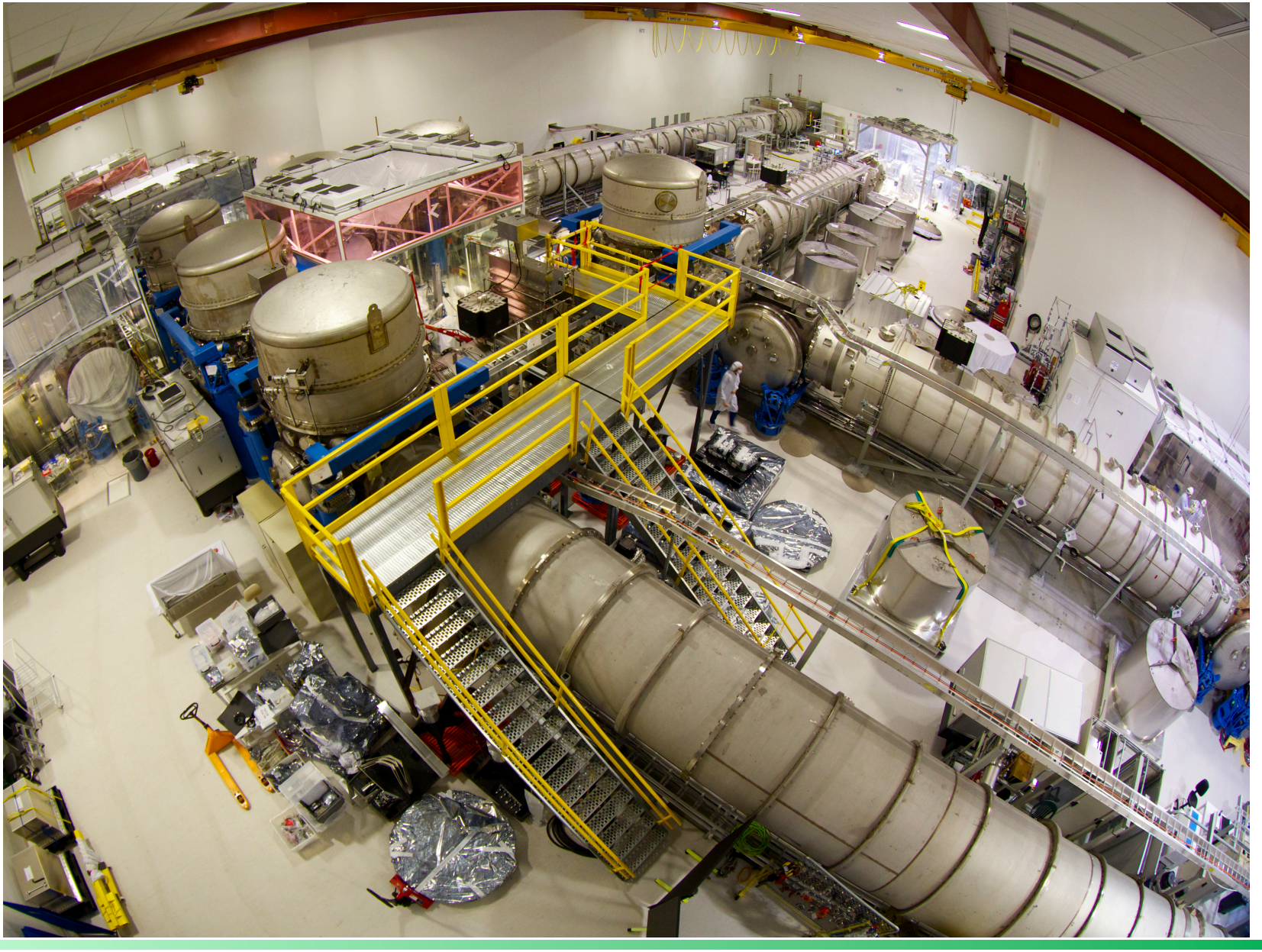
LIGO Hanford Observatory

California Institute of Technology

Astronomy on Tap, Seattle
28 Sept 2016

LIGO Hanford Observatory



LIGO History

1972: Internal MIT document by Rai Weiss details noise sources and mitigation techniques using laser interferometers for gravitational wave detection

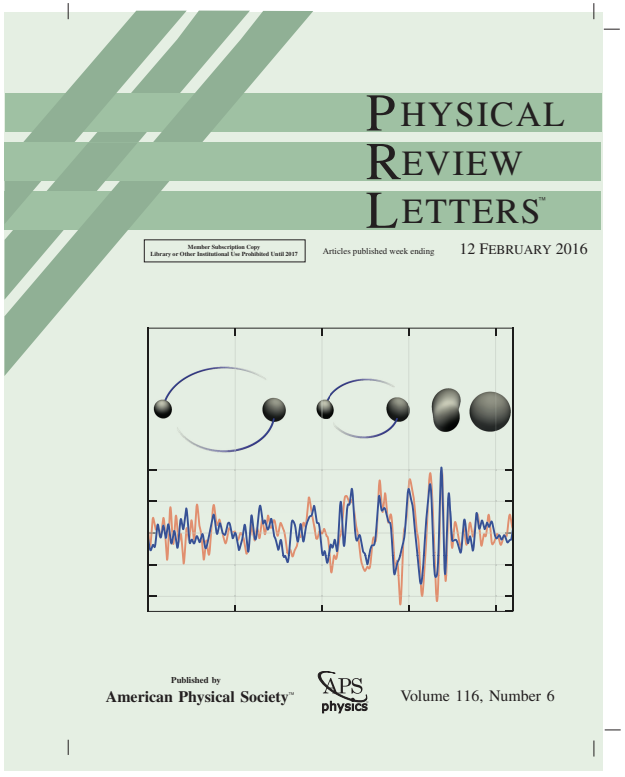
1989: Caltech & MIT proposal to the NSF for construction of LIGO
Both Initial LIGO and Advanced LIGO included

2002: Initial LIGO's Science Run 1

2010: Initial / Enhanced LIGO's Science Run 6 ends

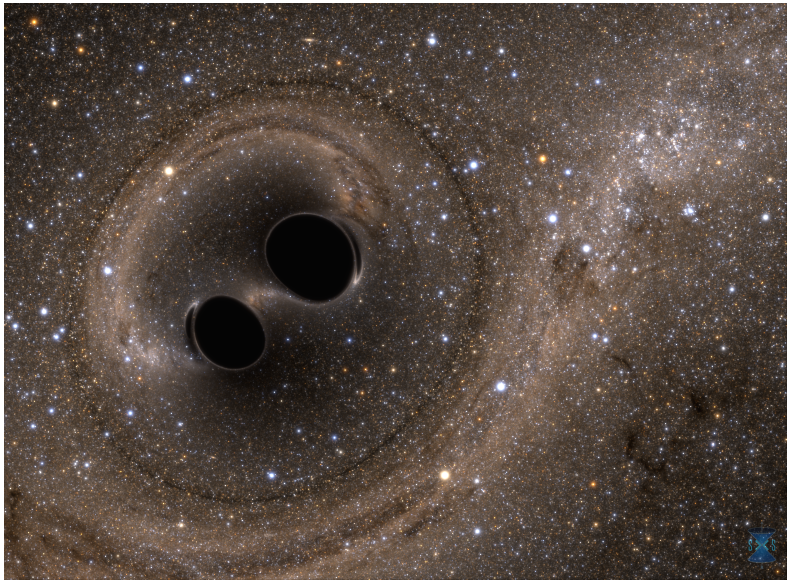
2015: Advanced LIGO's Observing Run 1 begins
First direct detection of gravitational waves

2016: Detection of gravitational waves announced

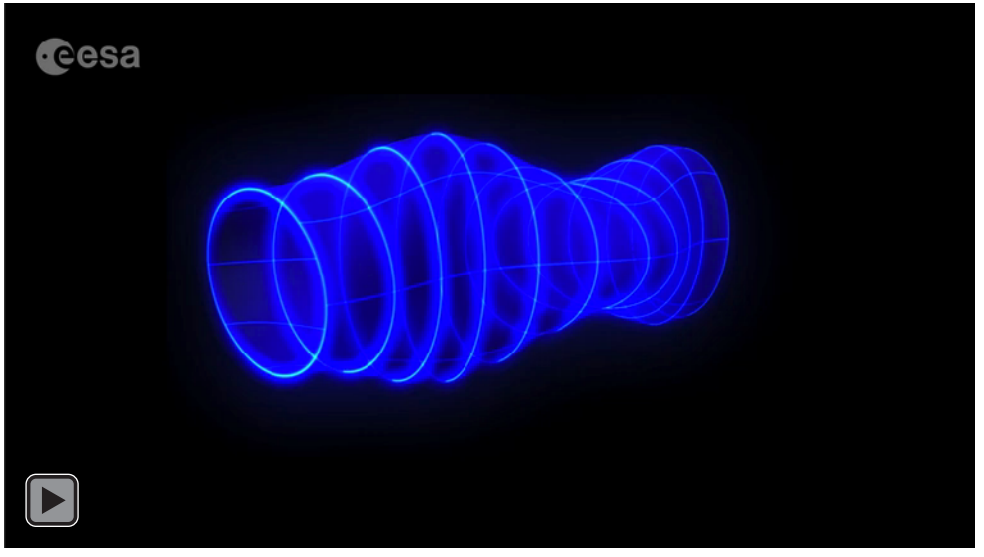


LIGO Gravitational waves affect spacetime

Black hole binary inspiralling

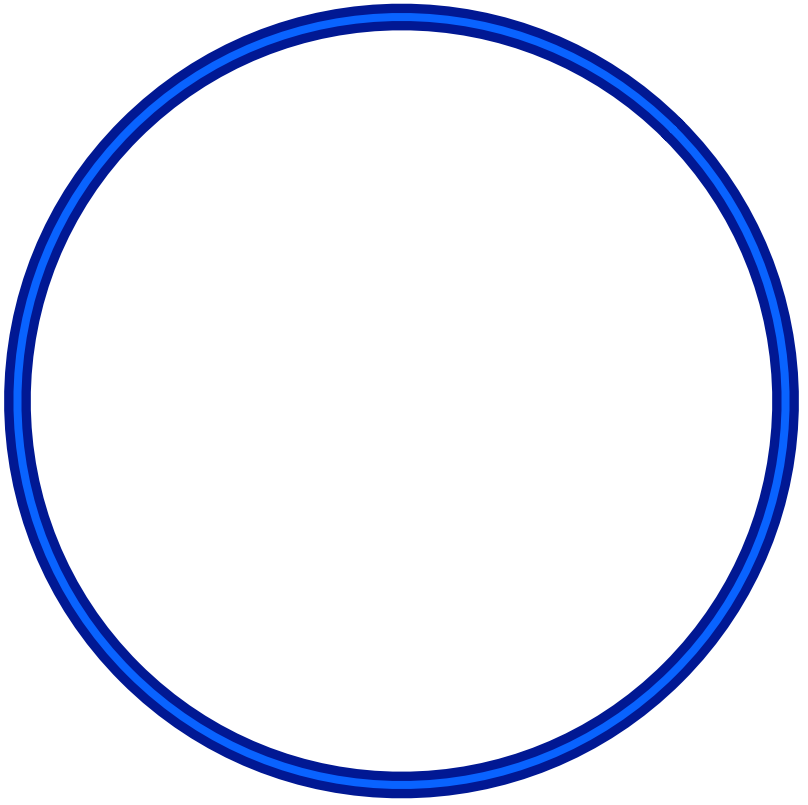


Spacetime stretches and squeezes as gravitational waves pass

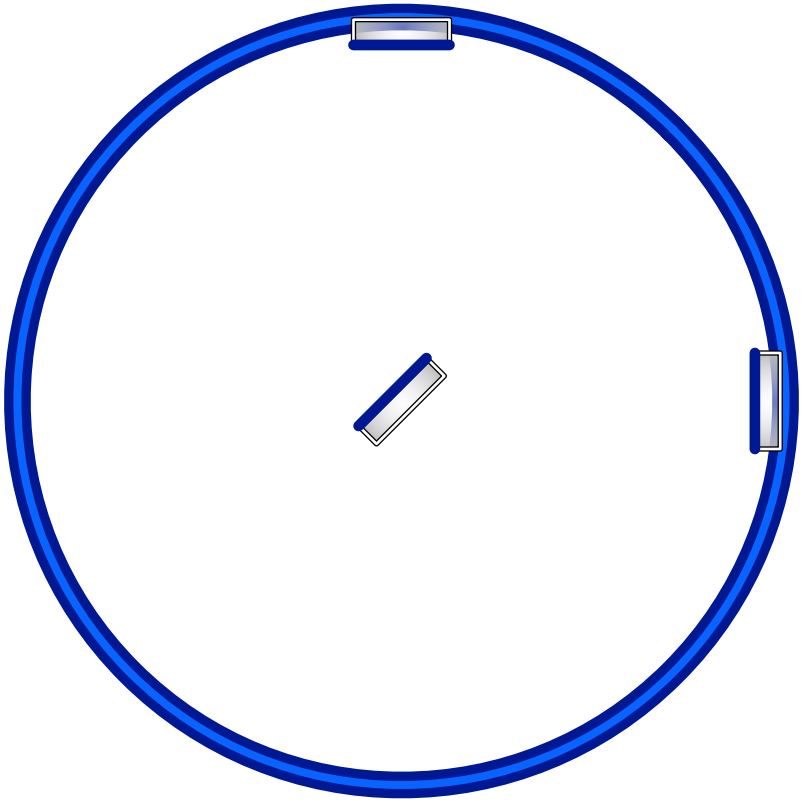


LIGO measures the distortions of spacetime

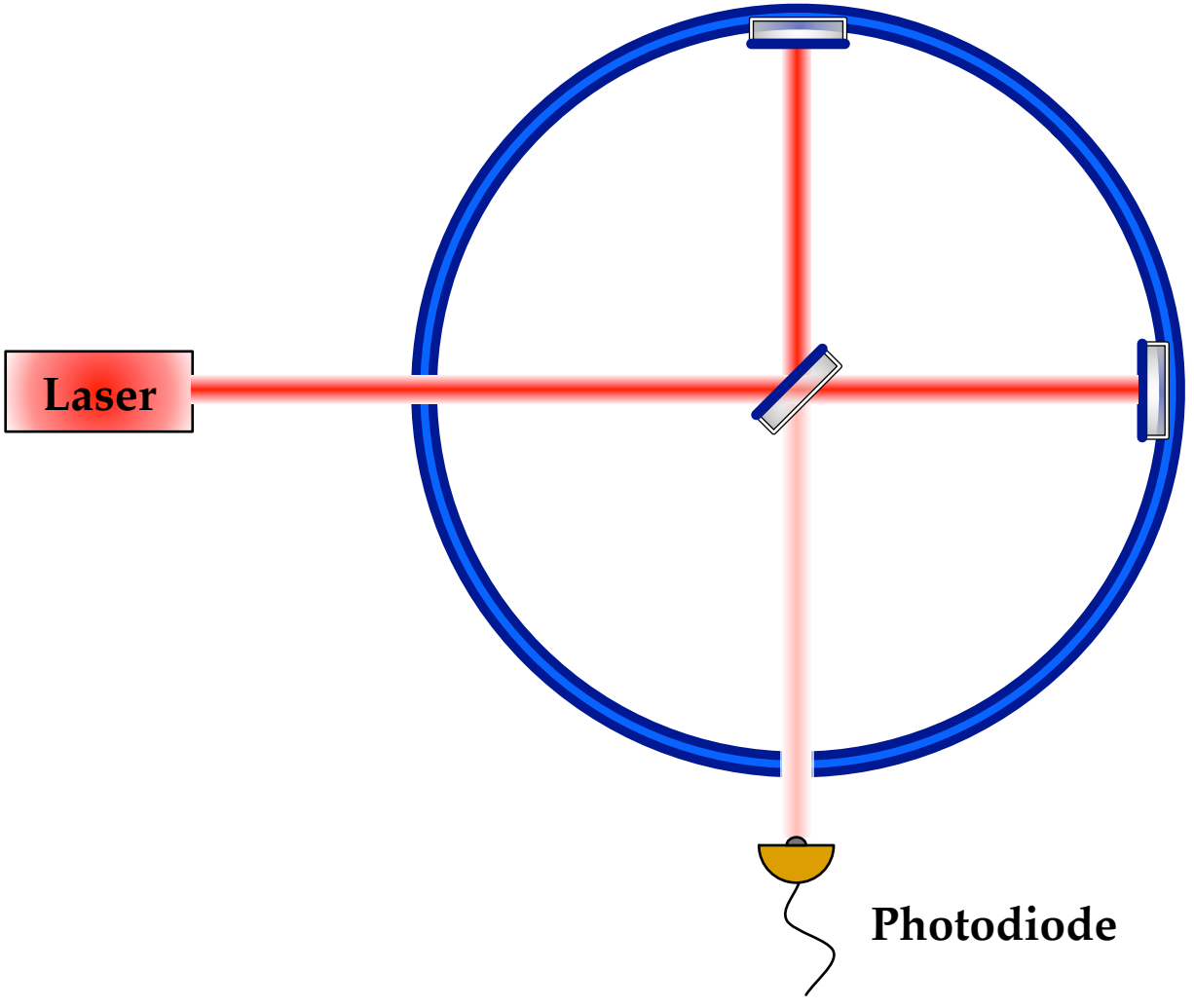
Measuring Spacetime



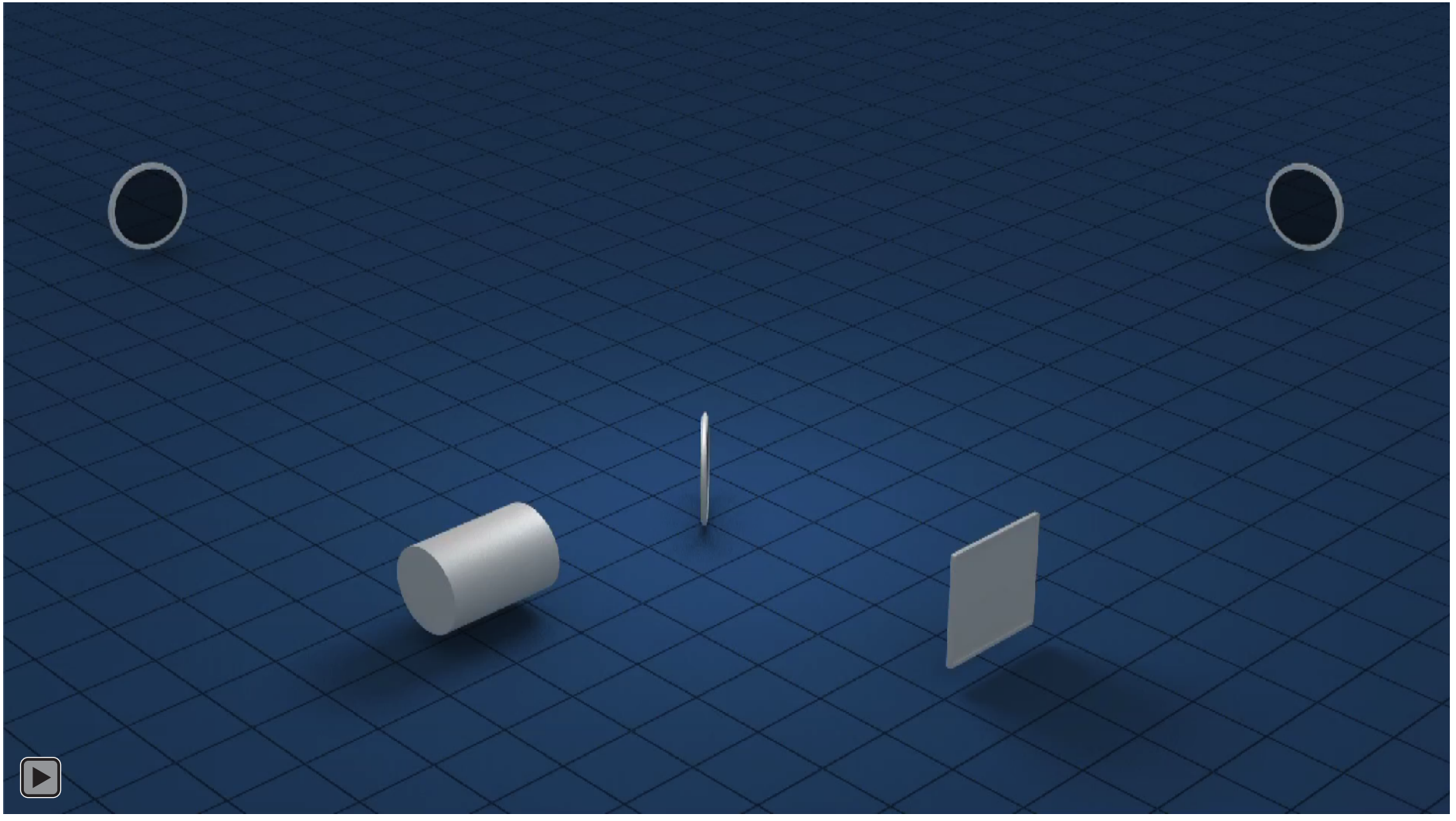
Measuring Spacetime



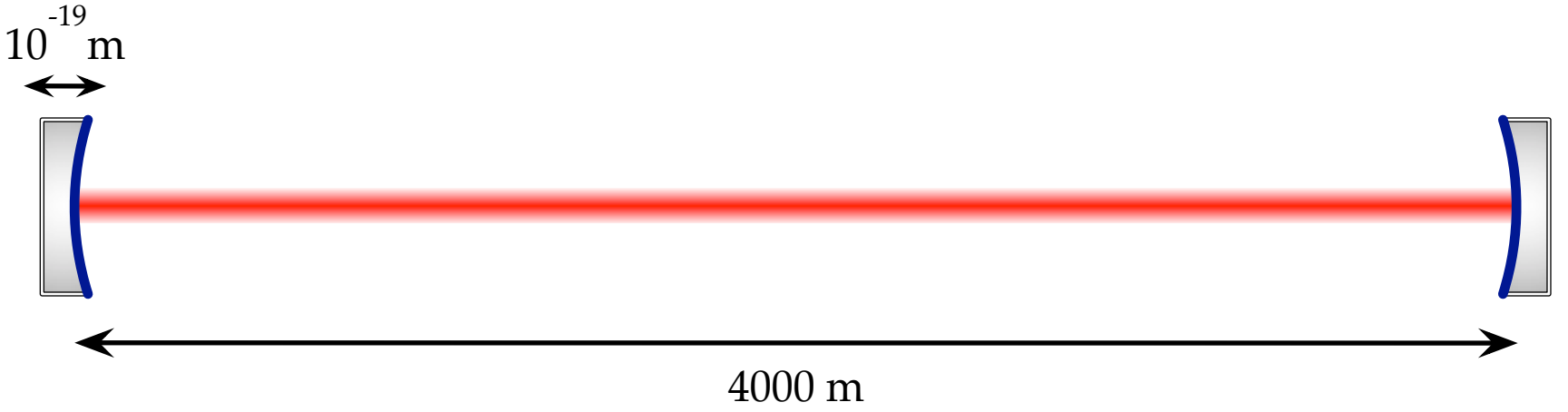
Measuring Spacetime



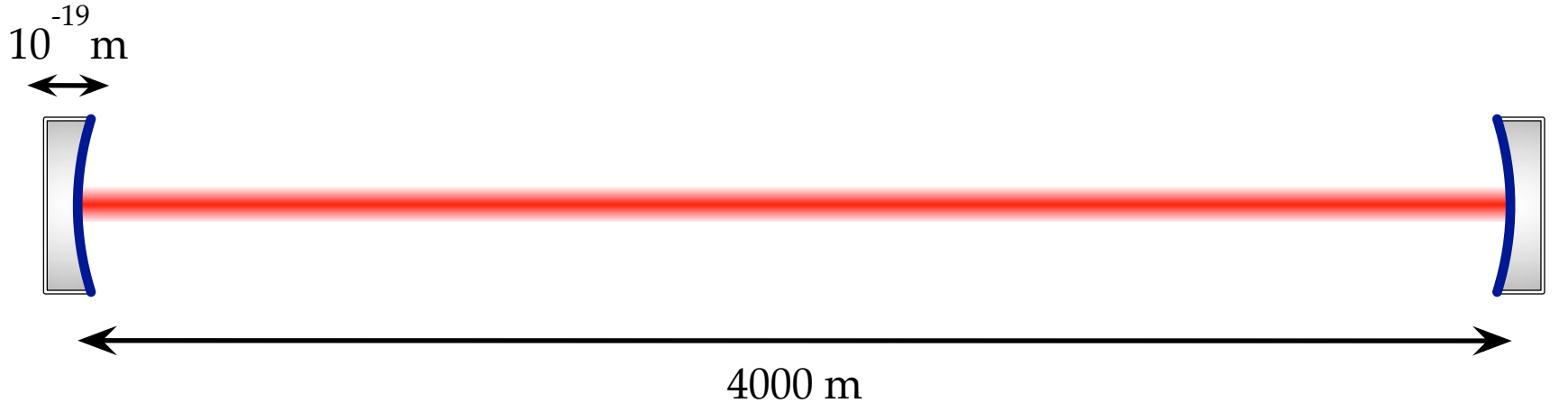
How Do We Measure?

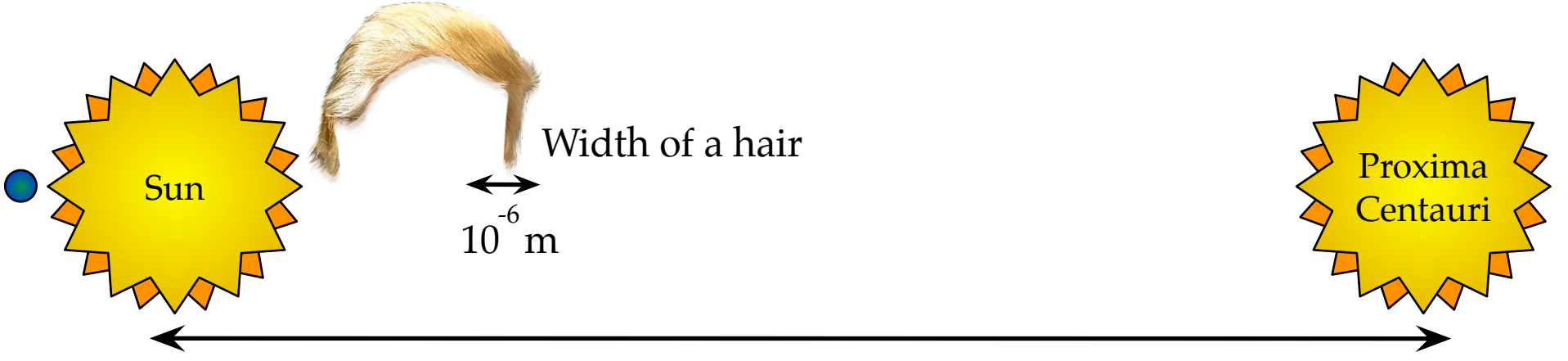


How Precise?

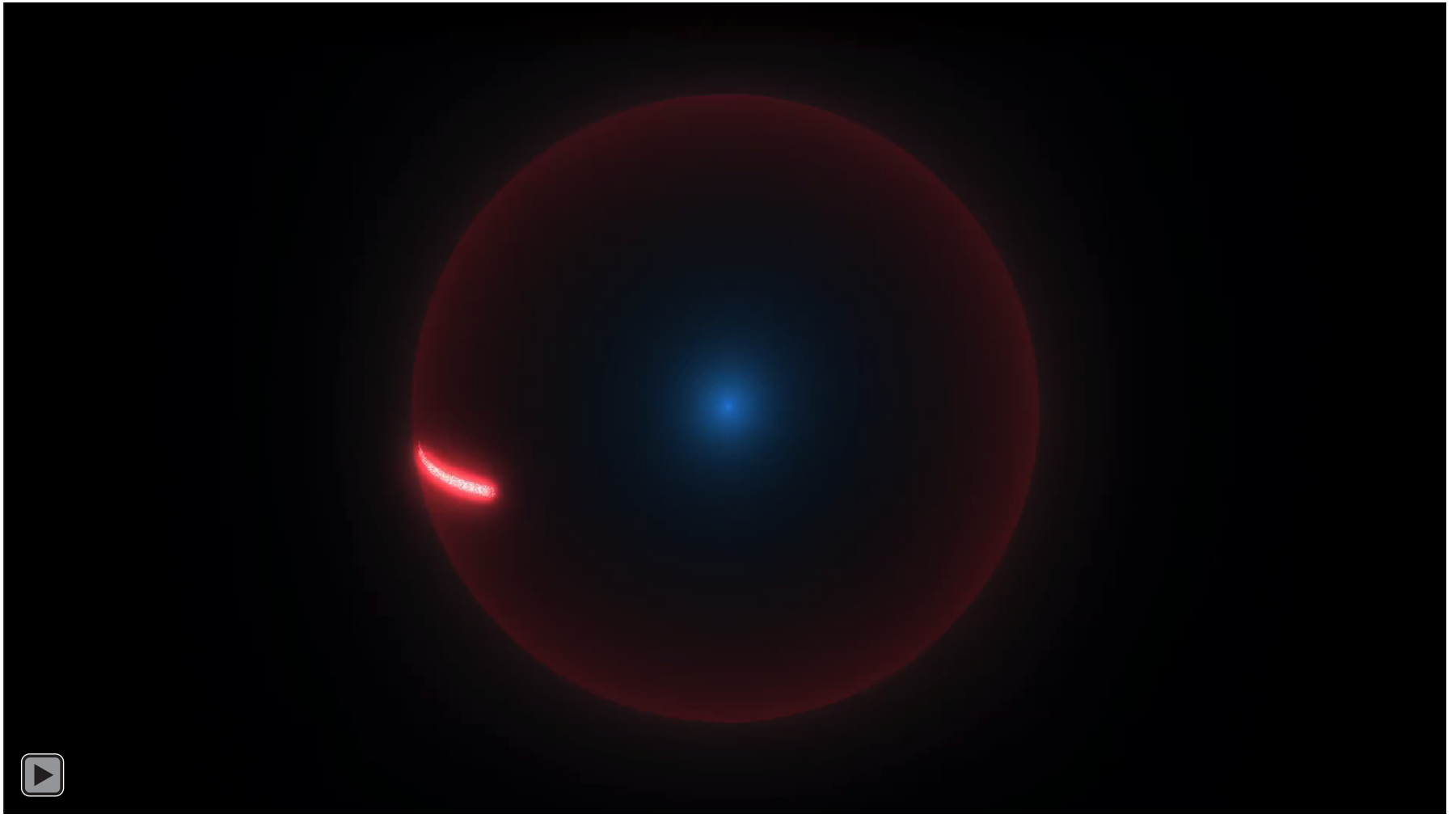


How Precise?


10^-19 m
4000 m


Sun
Width of a hair
10^-6 m
Proxima Centauri
4.24 light years = 4x10^16 m

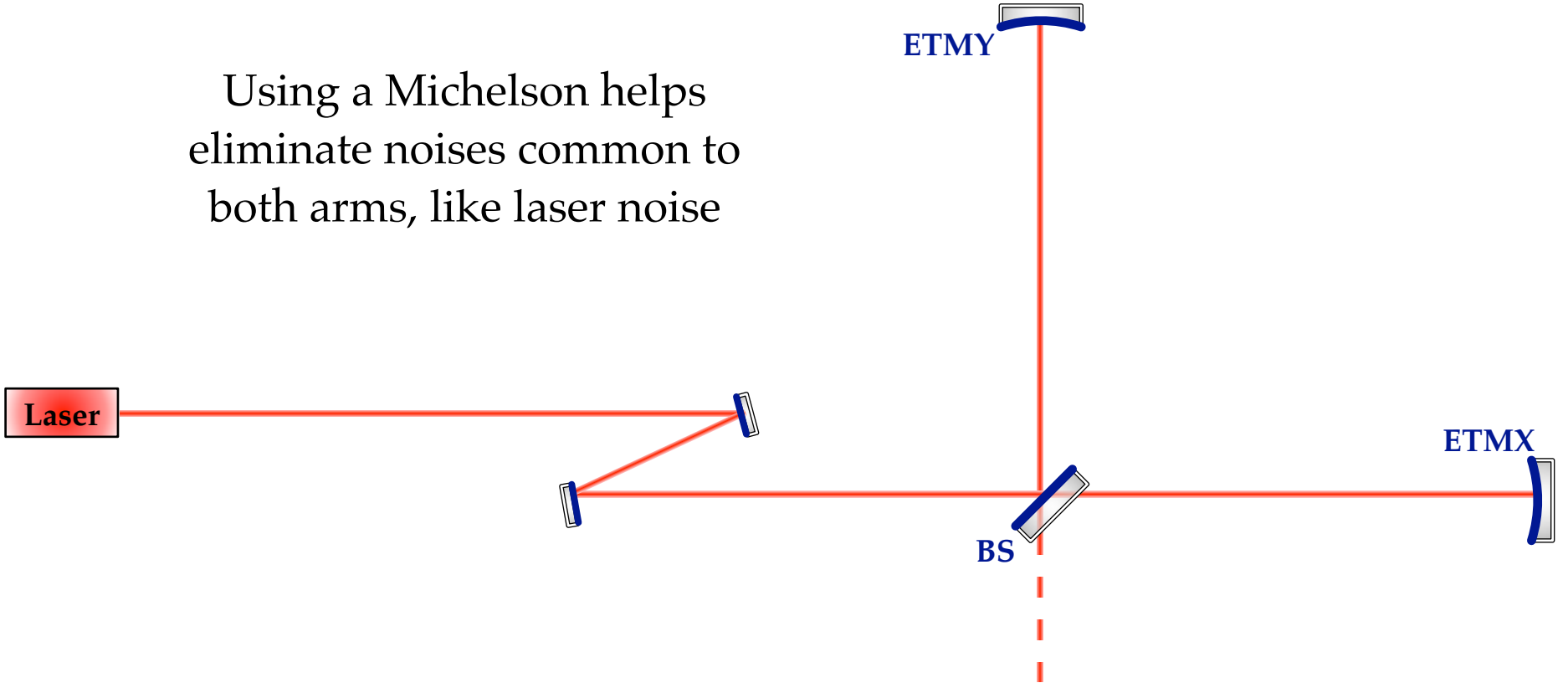
How Precise?



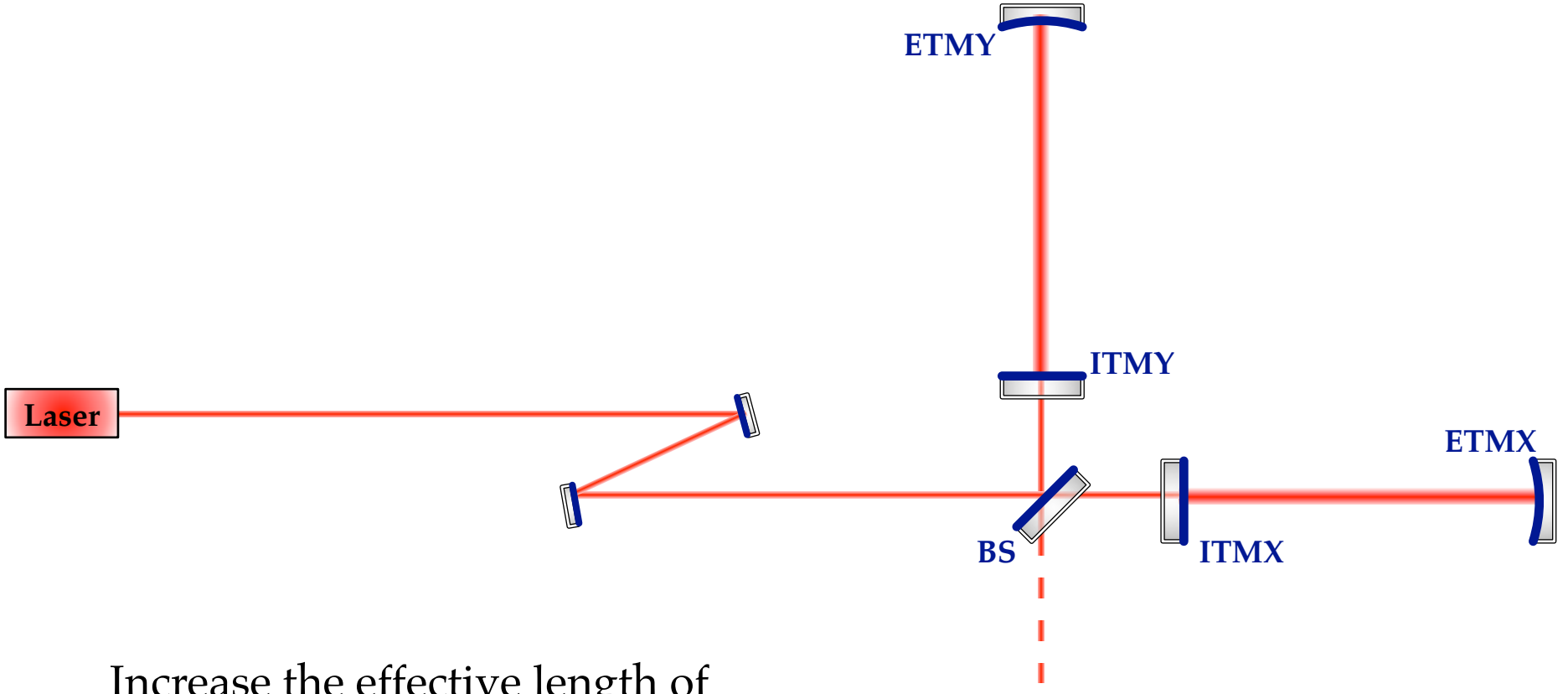
Michelson Foundation

Michelson Foundation

Using a Michelson helps eliminate noises common to both arms, like laser noise



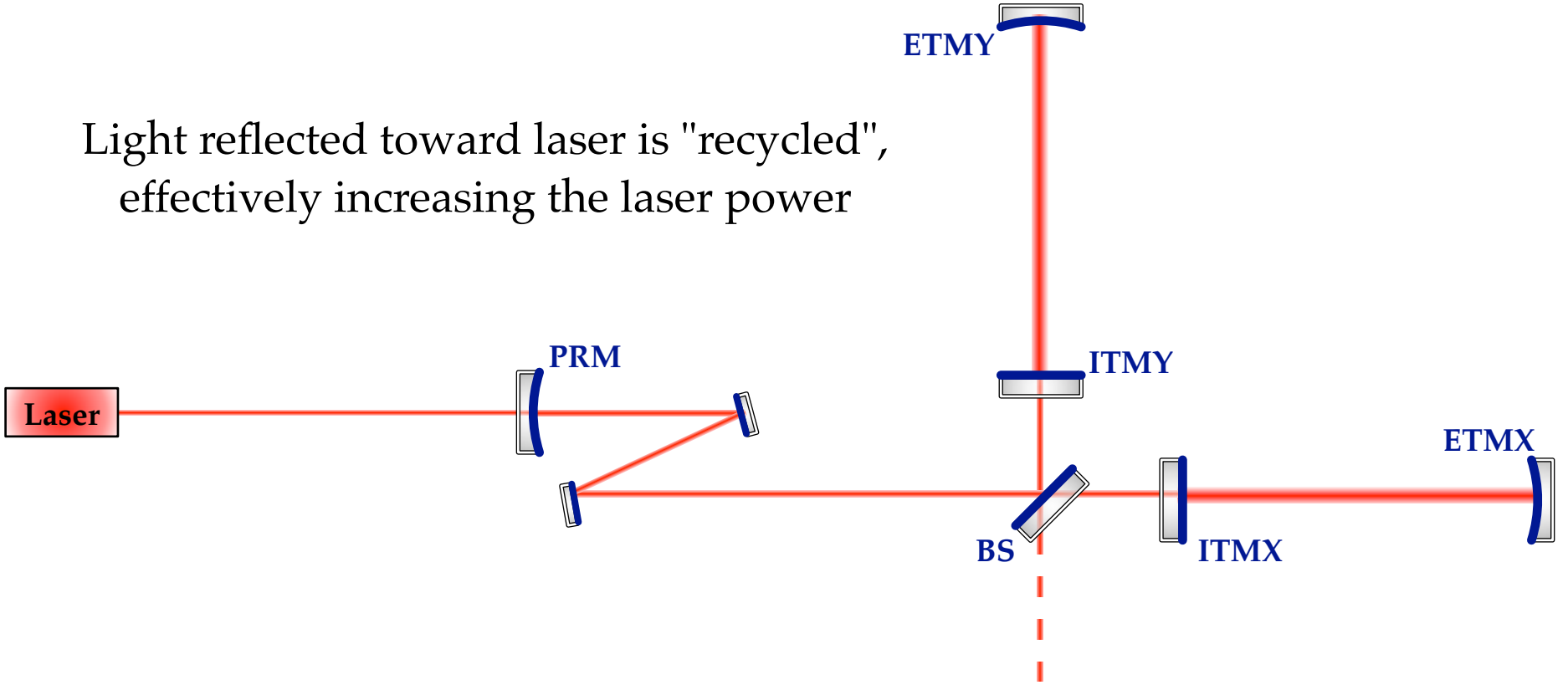
Fabry-Pérot Arm Cavities



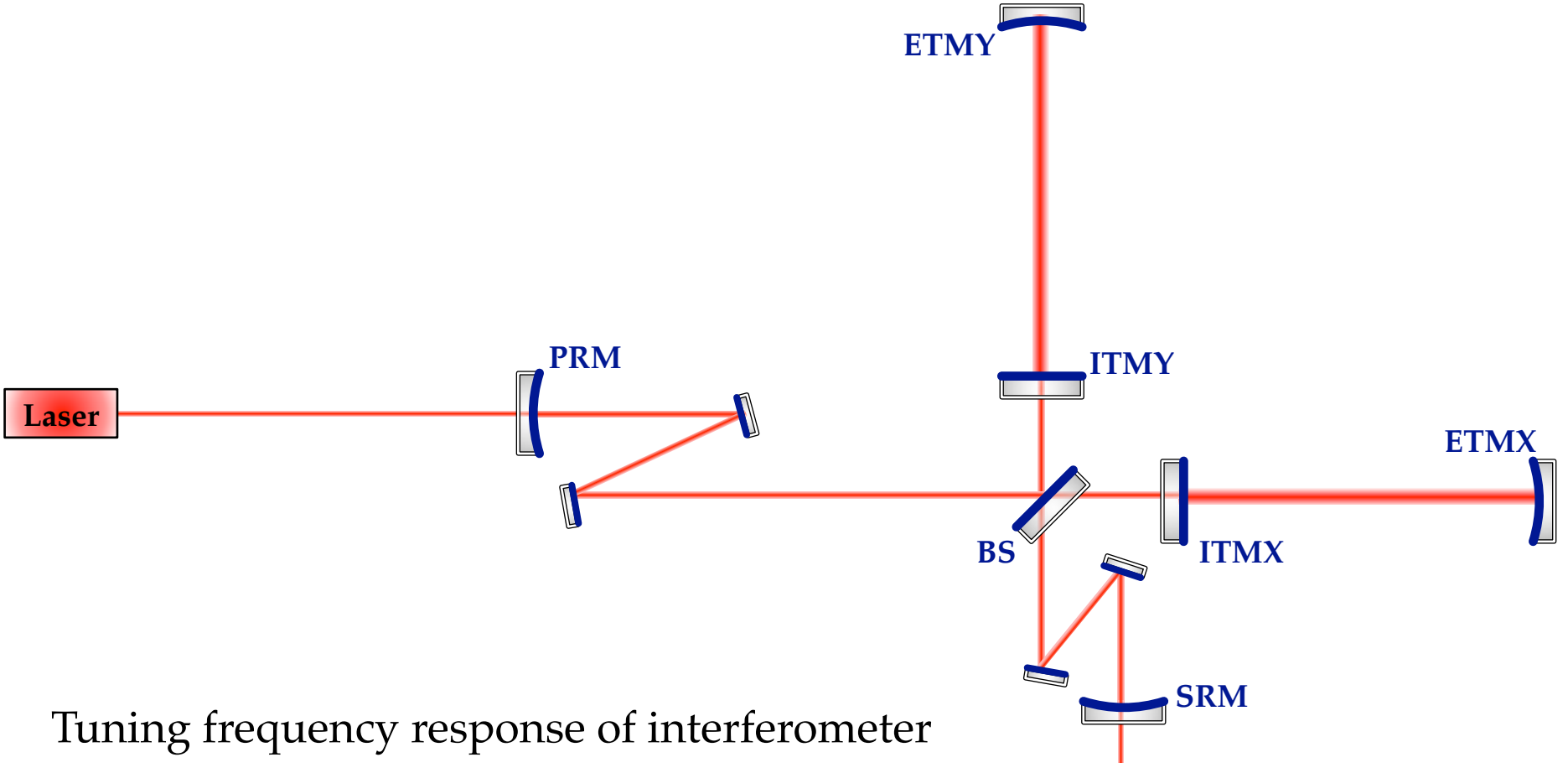
Increase the effective length of the arms of the Michelson

Power Recycling

Light reflected toward laser is "recycled", effectively increasing the laser power



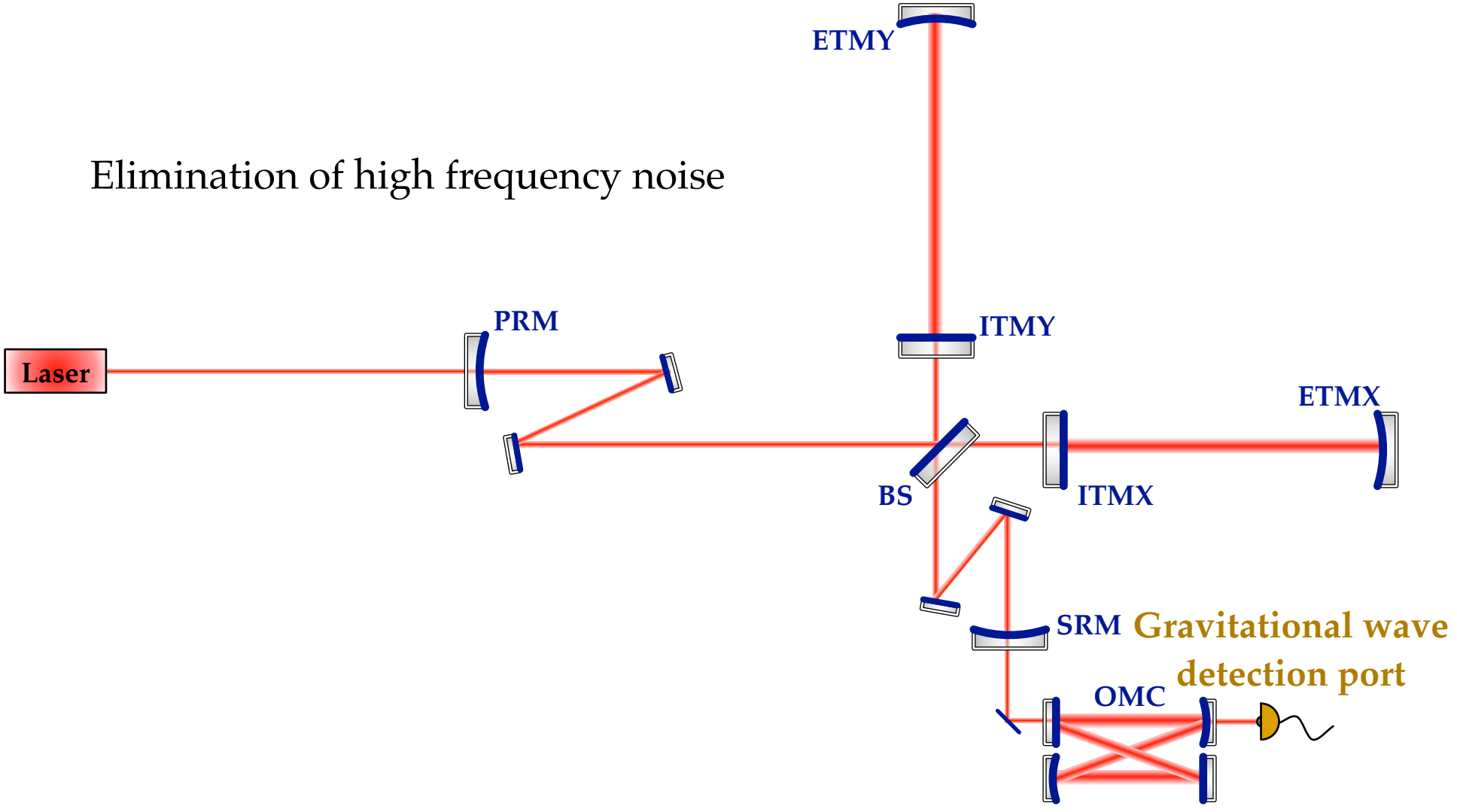
Signal Extraction



Tuning frequency response of interferometer

Readout of Gravitational Waves

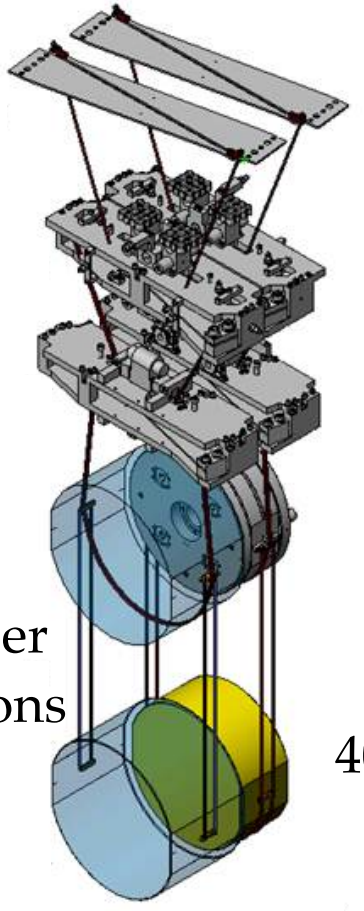
Elimination of high frequency noise



Isolation from Ground Motion

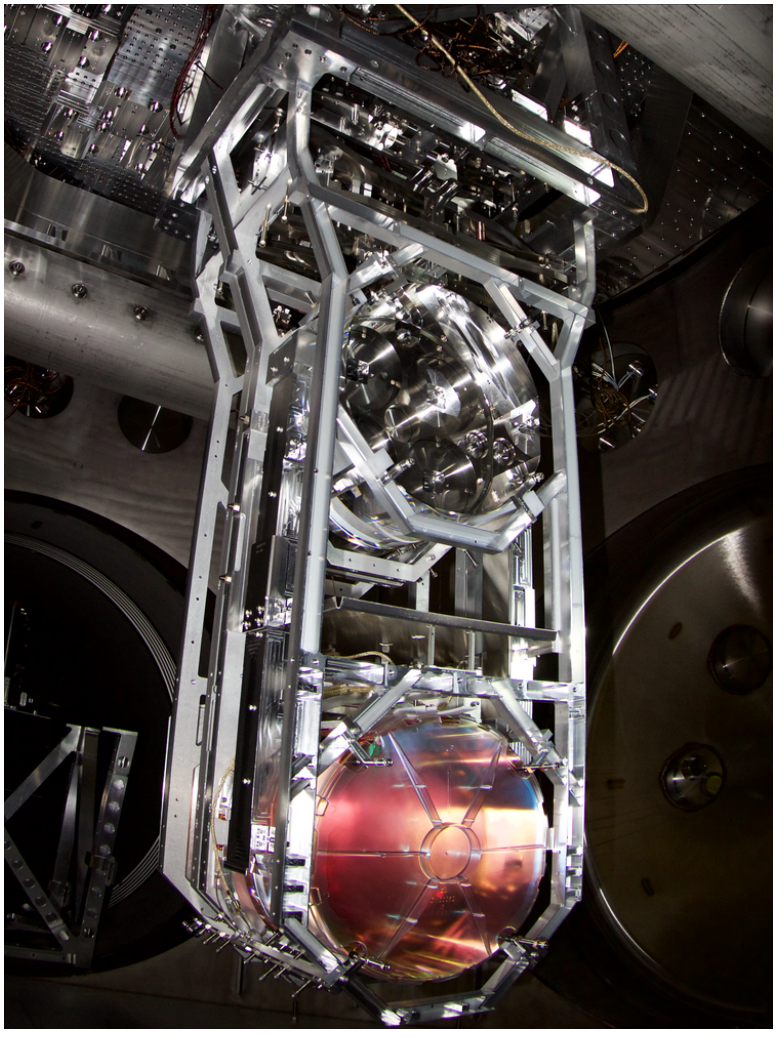
Quadruple pendulum:

$\frac{1}{f^8}$ isolation



Glass fiber suspensions

40kg mirrors



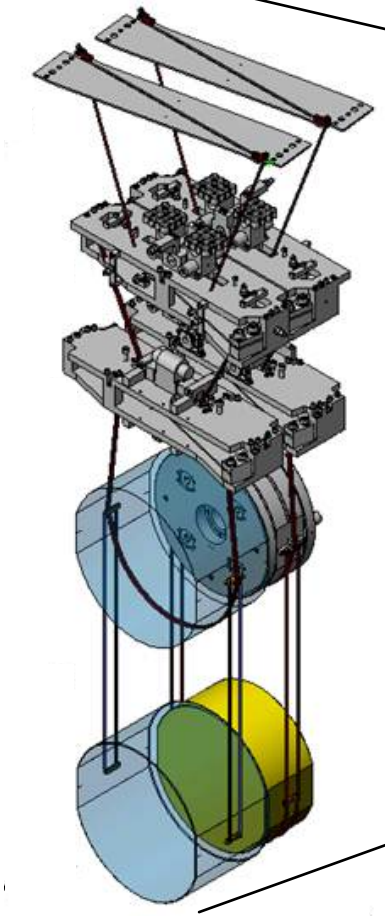
LIGO-P1200056

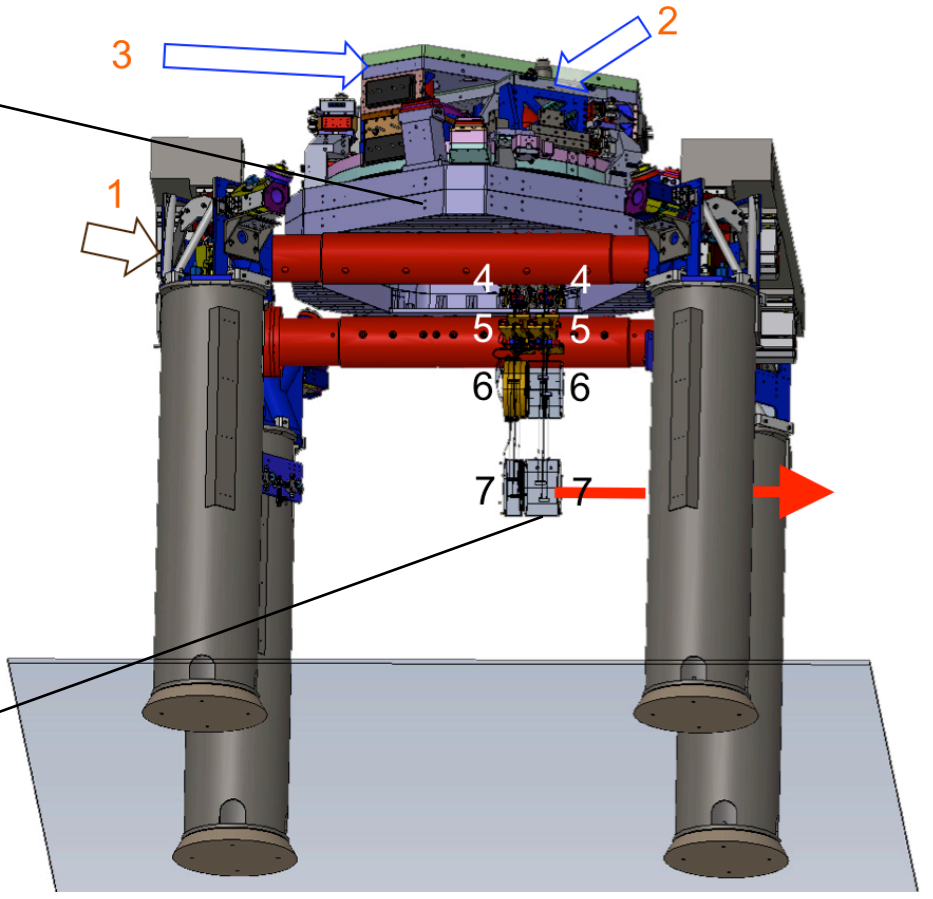
Isolation from Ground Motion

Quadruple pendulum:

$\frac{1}{f^8}$ isolation

Together, more than 10^7 isolation above 10 Hz

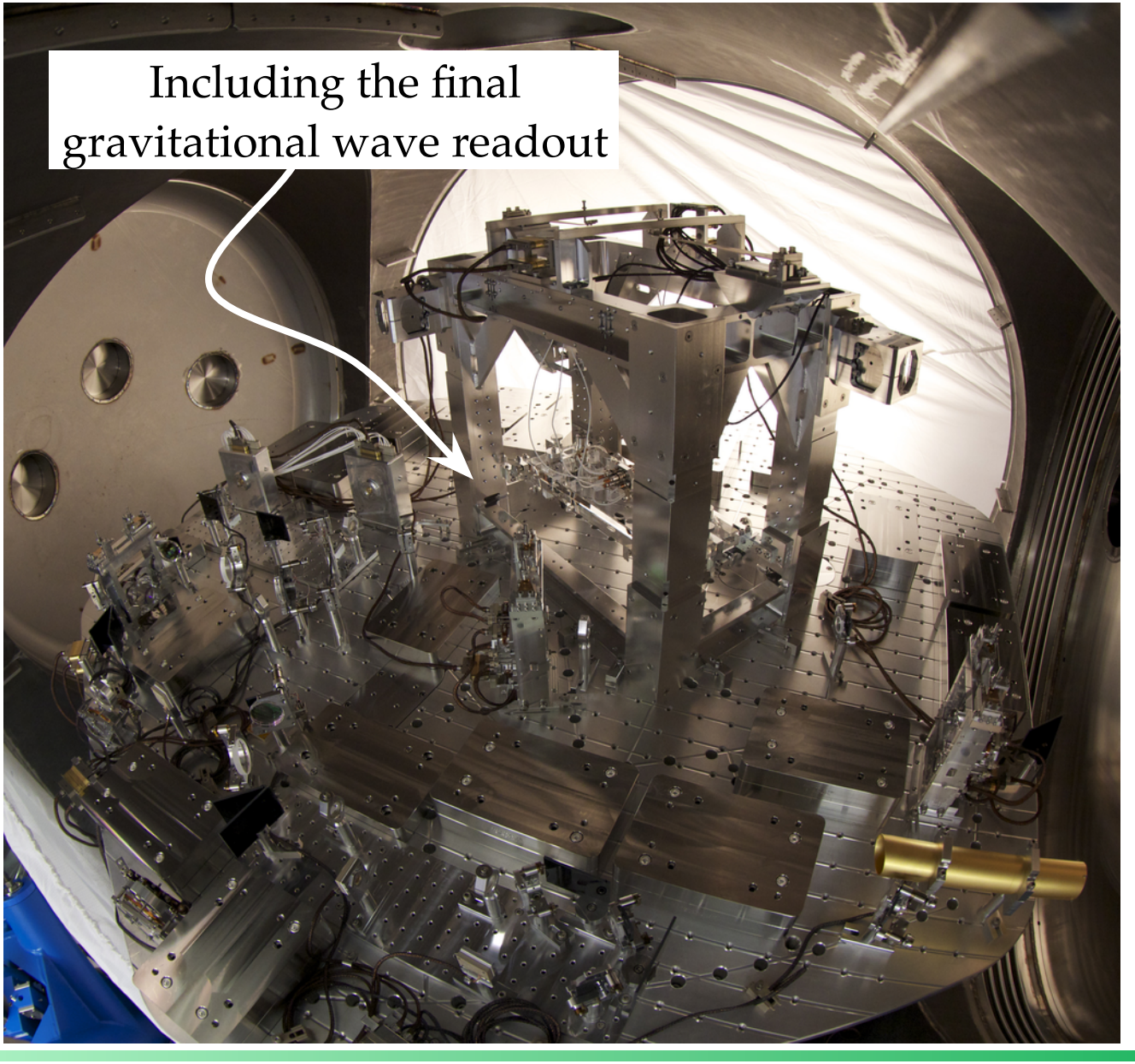




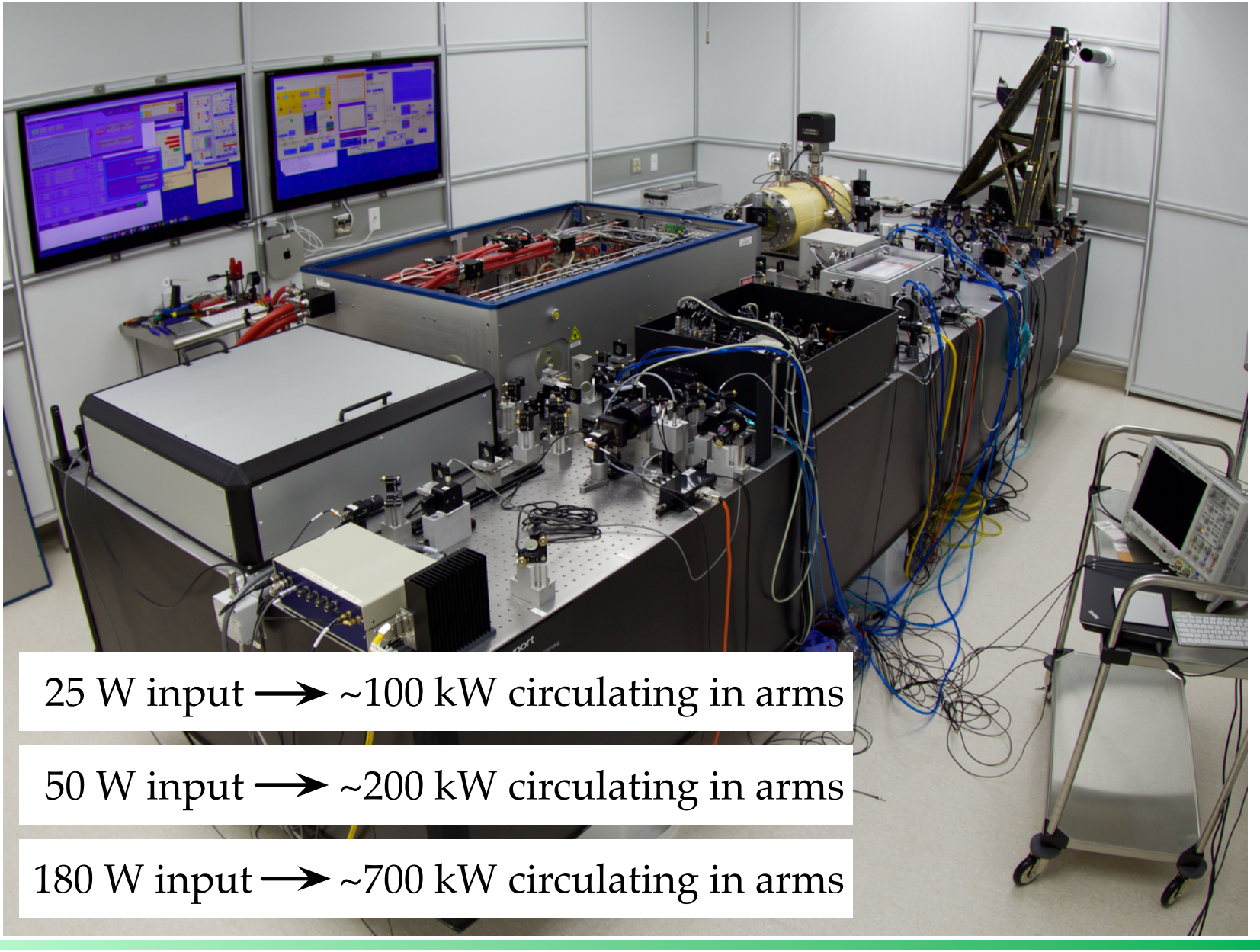
LIGO-P1200056

LIGO-G1200556

Everything in Vacuum



High Power Laser



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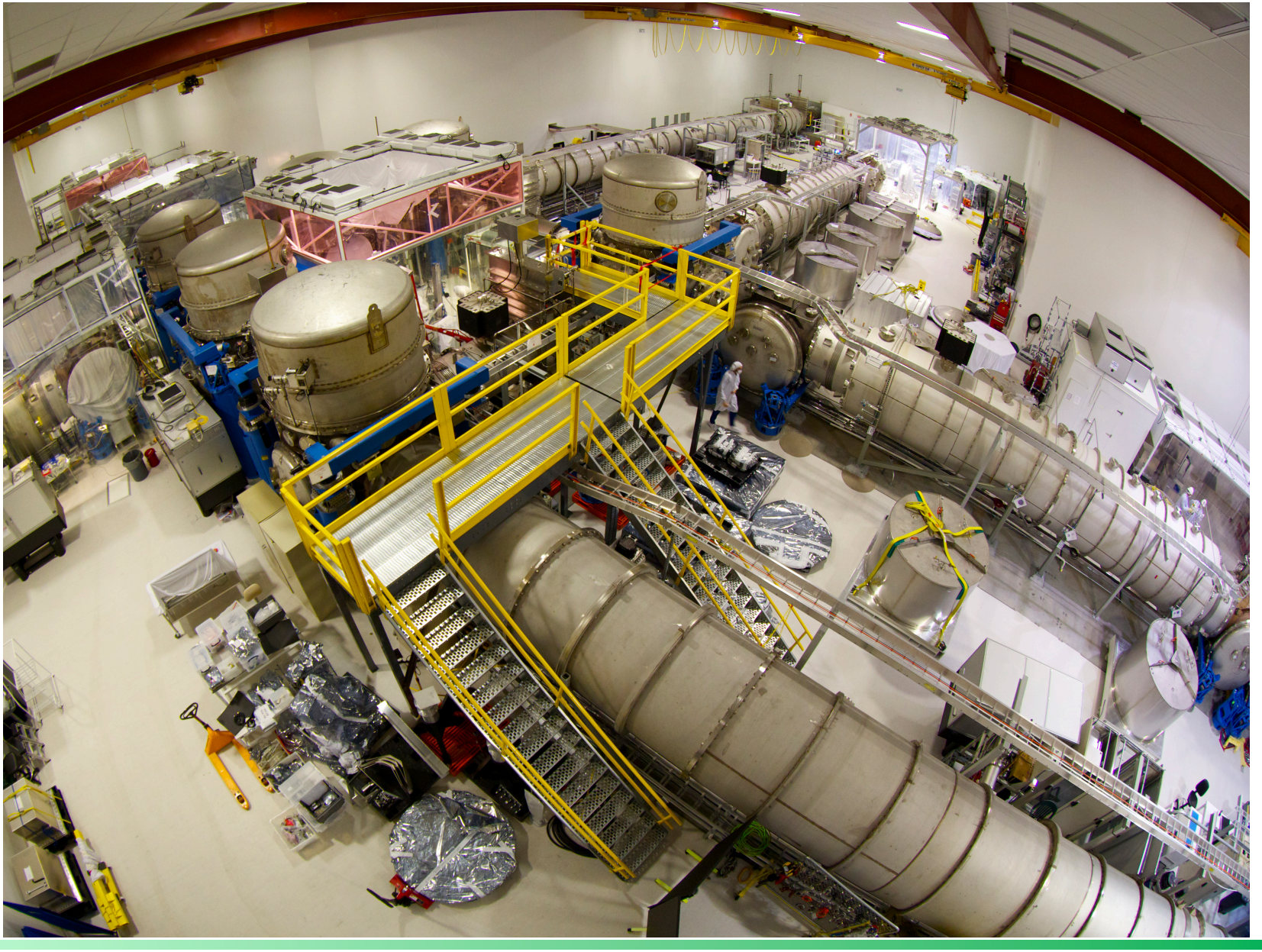

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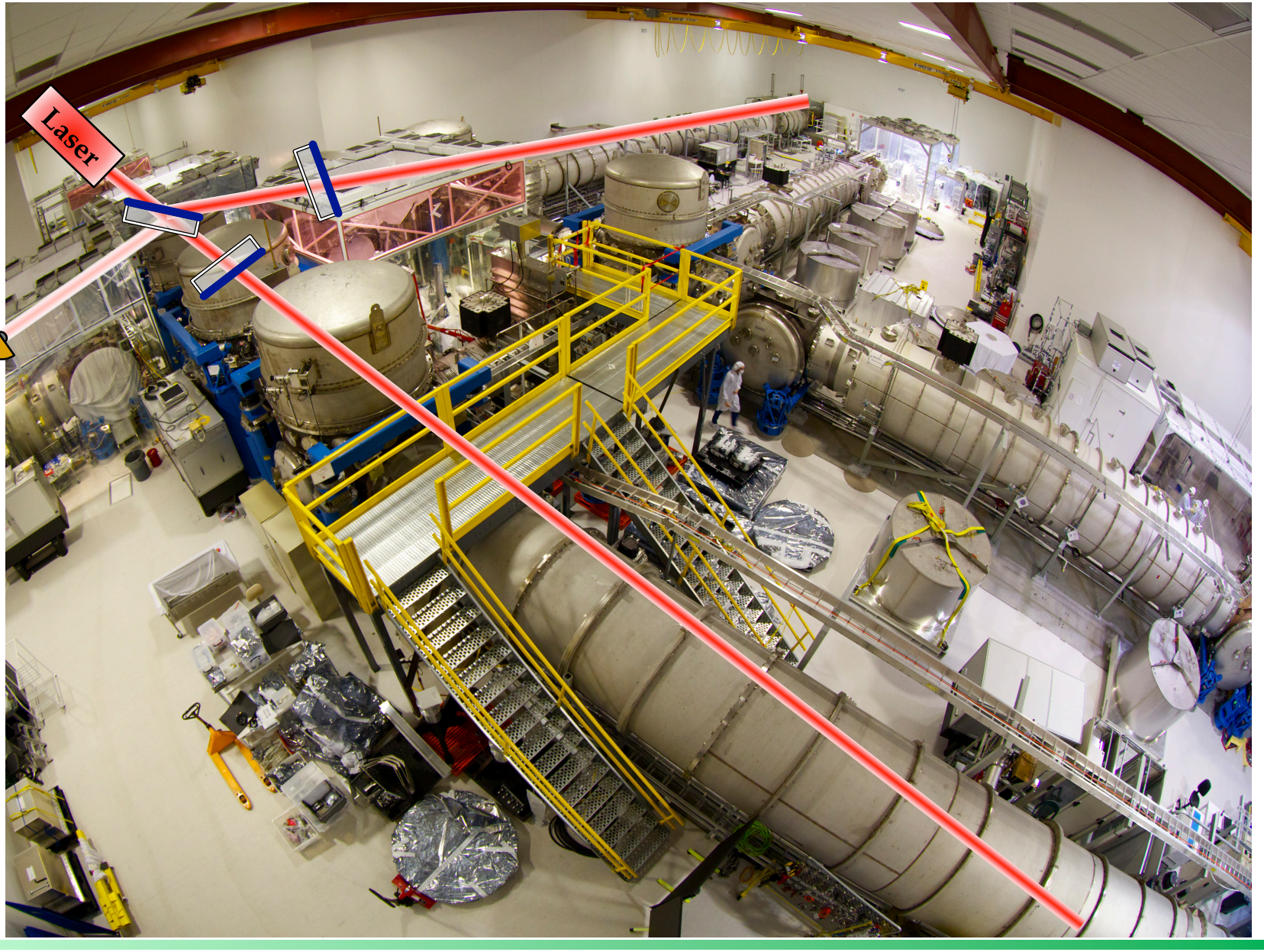
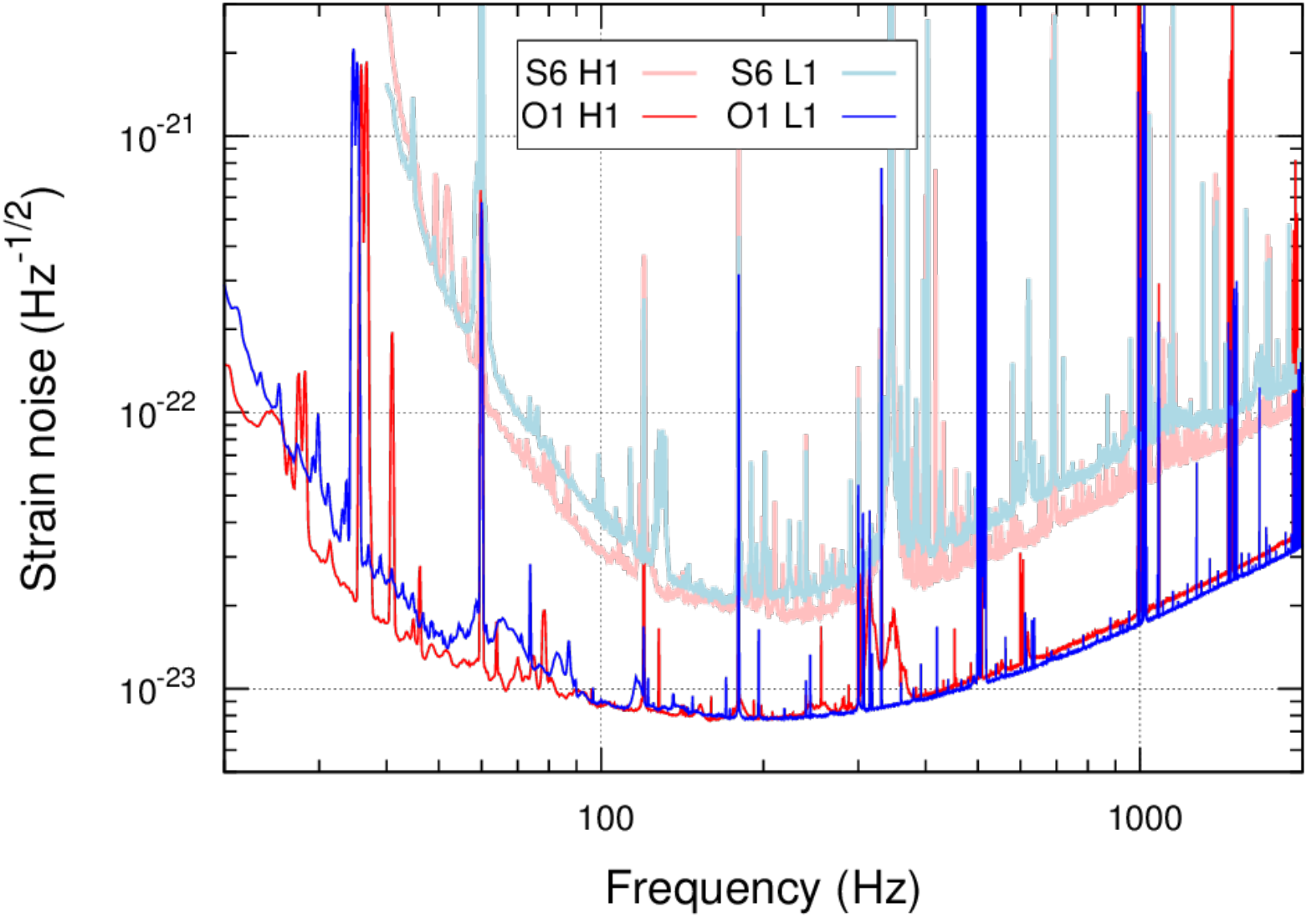
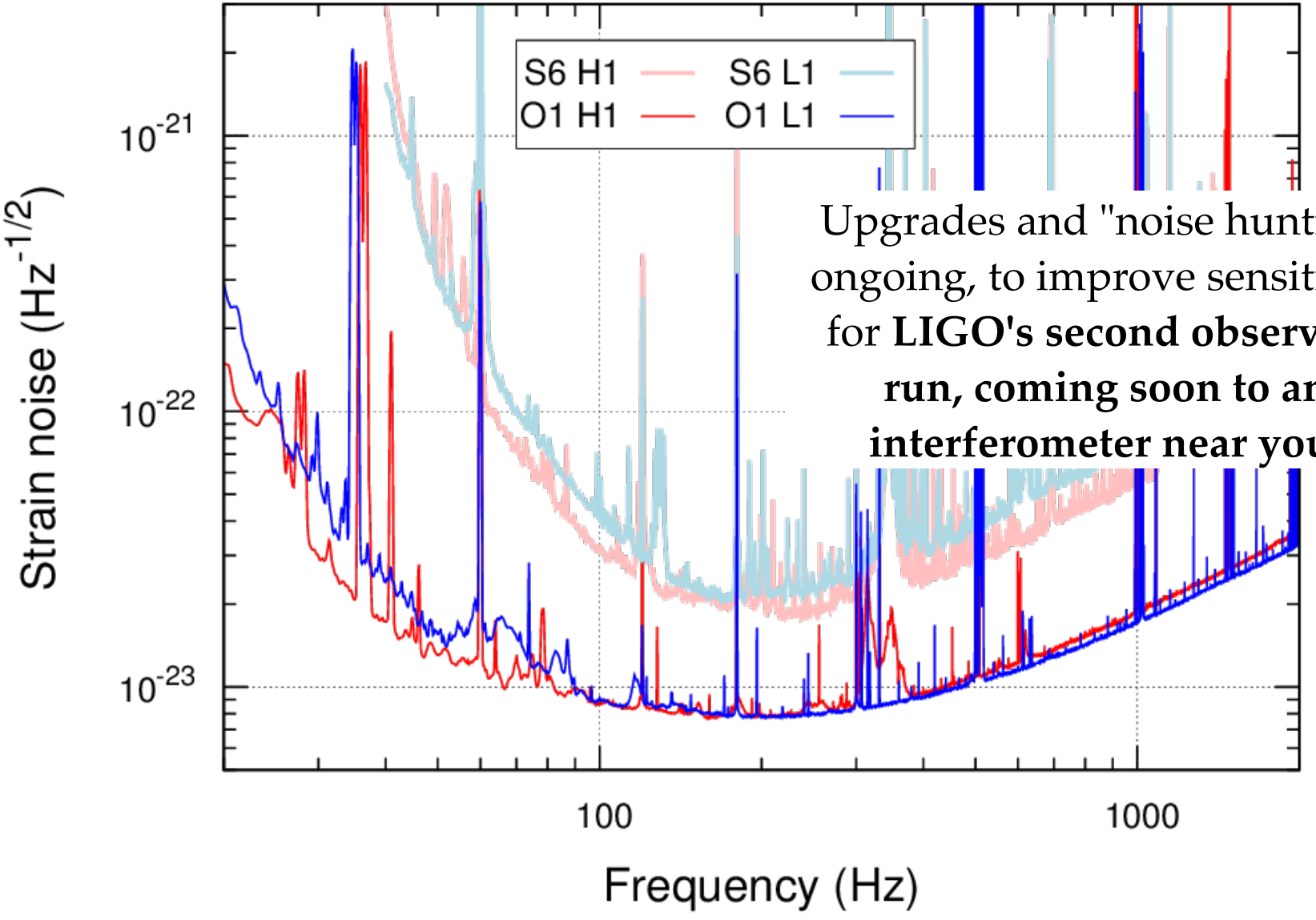


Sensitivity of Observing Run 1



LIGO

Sensitivity of Observing Run 1



Upgrades and "noise hunting" ongoing, to improve sensitivity for **LIGO's second observing run, coming soon to an interferometer near you!**

LIGO