

# The Present and Near Future of LIGO

Jeff Kissel for the LSC

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Fifth Gulf Coast Gravity Meeting, April 17<sup>th</sup> 2009

LIGO-G0900349-v4

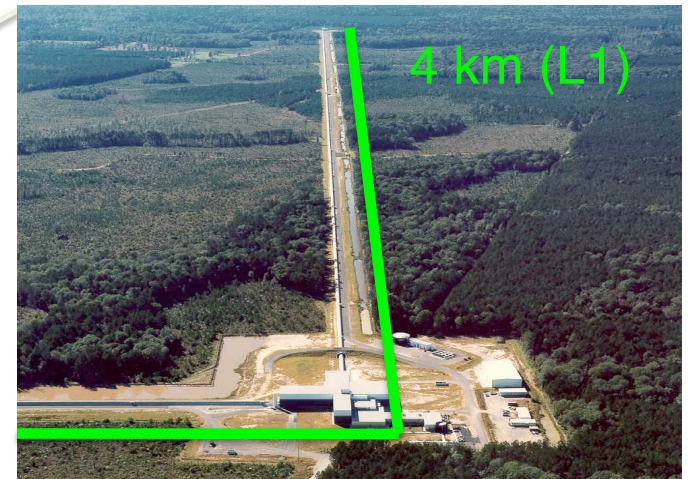
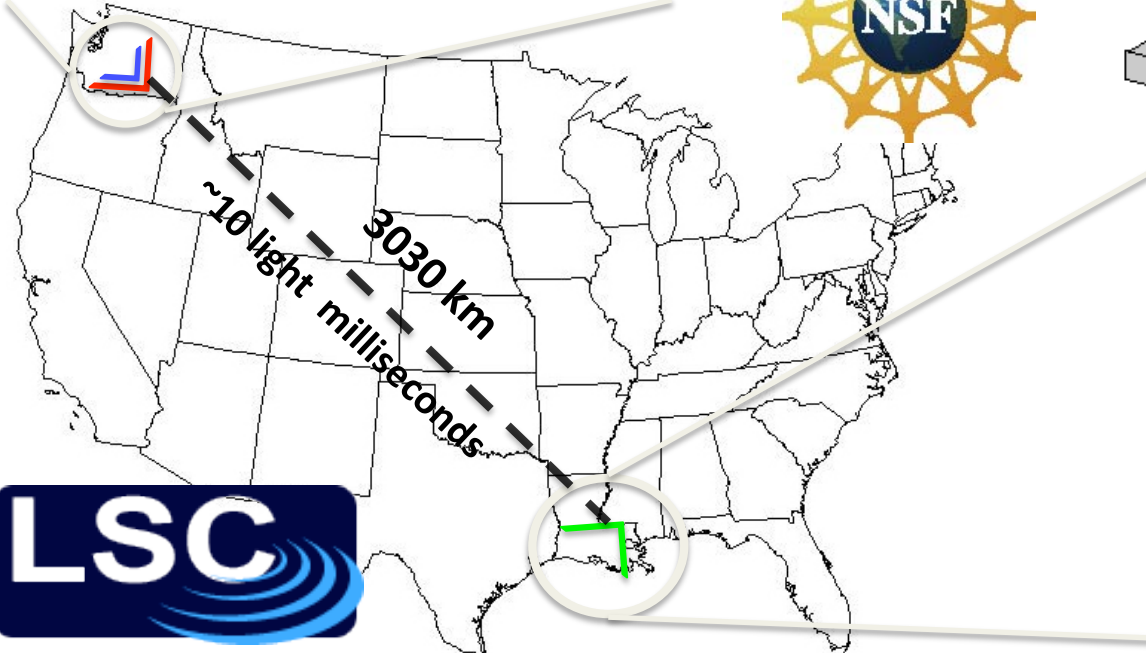
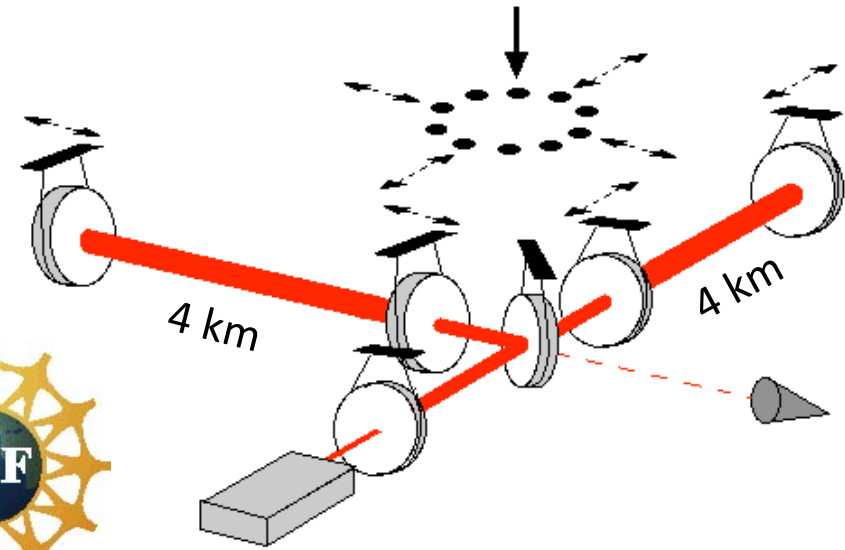
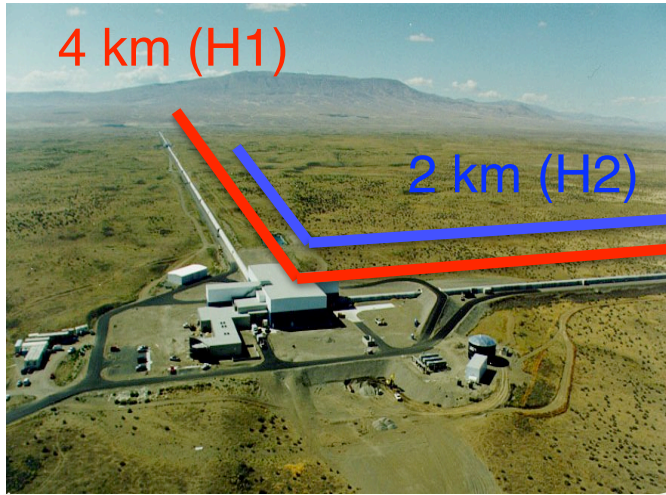
$$h^{kl}(t, \vec{x}) \approx \frac{2G}{c^4} \frac{1}{r} \frac{d^2}{dt^2} I^{kl}(t, \vec{x})$$



# The LIGO Interferometers



- Power-Recycled Michelson with Fabry-Perot Arms

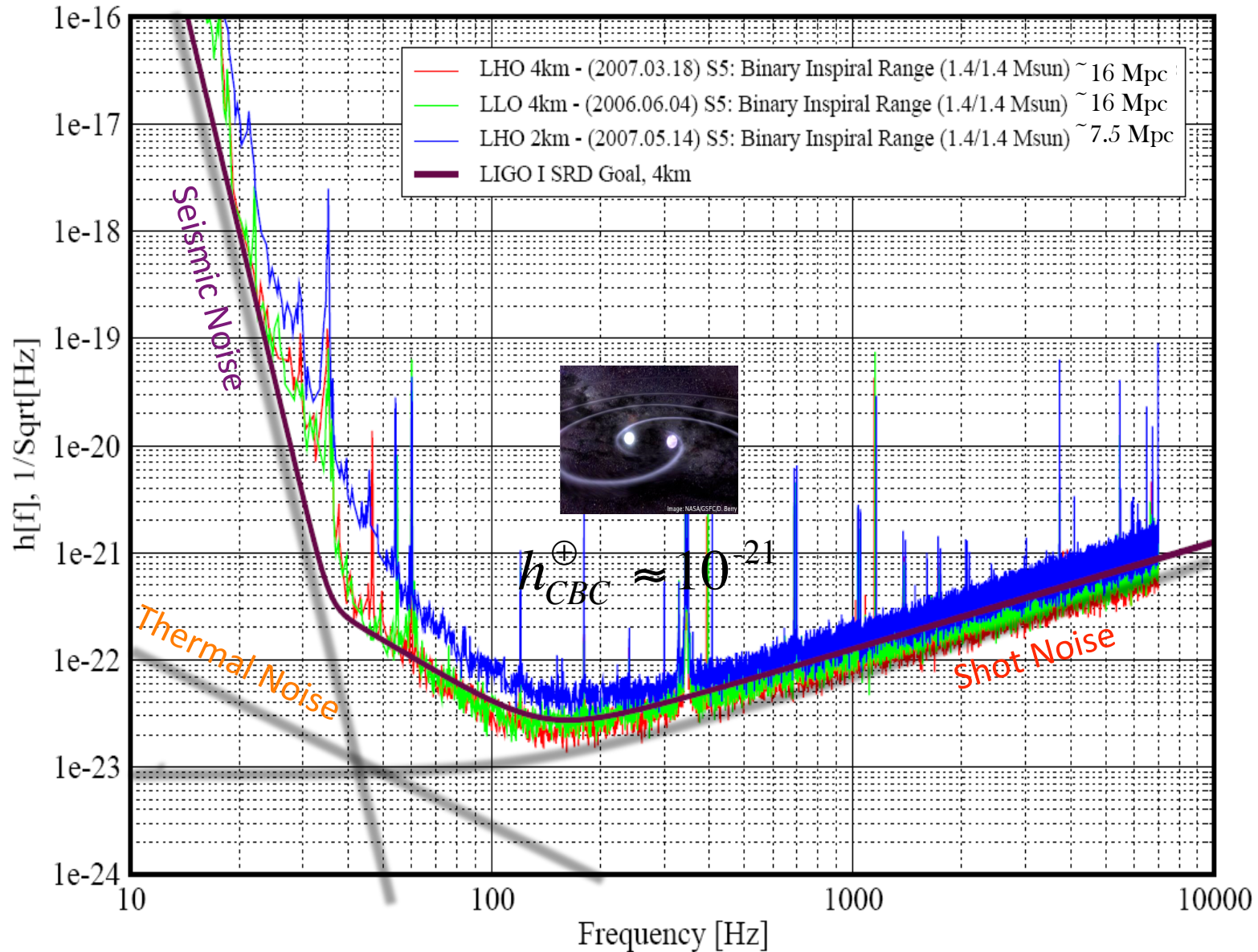


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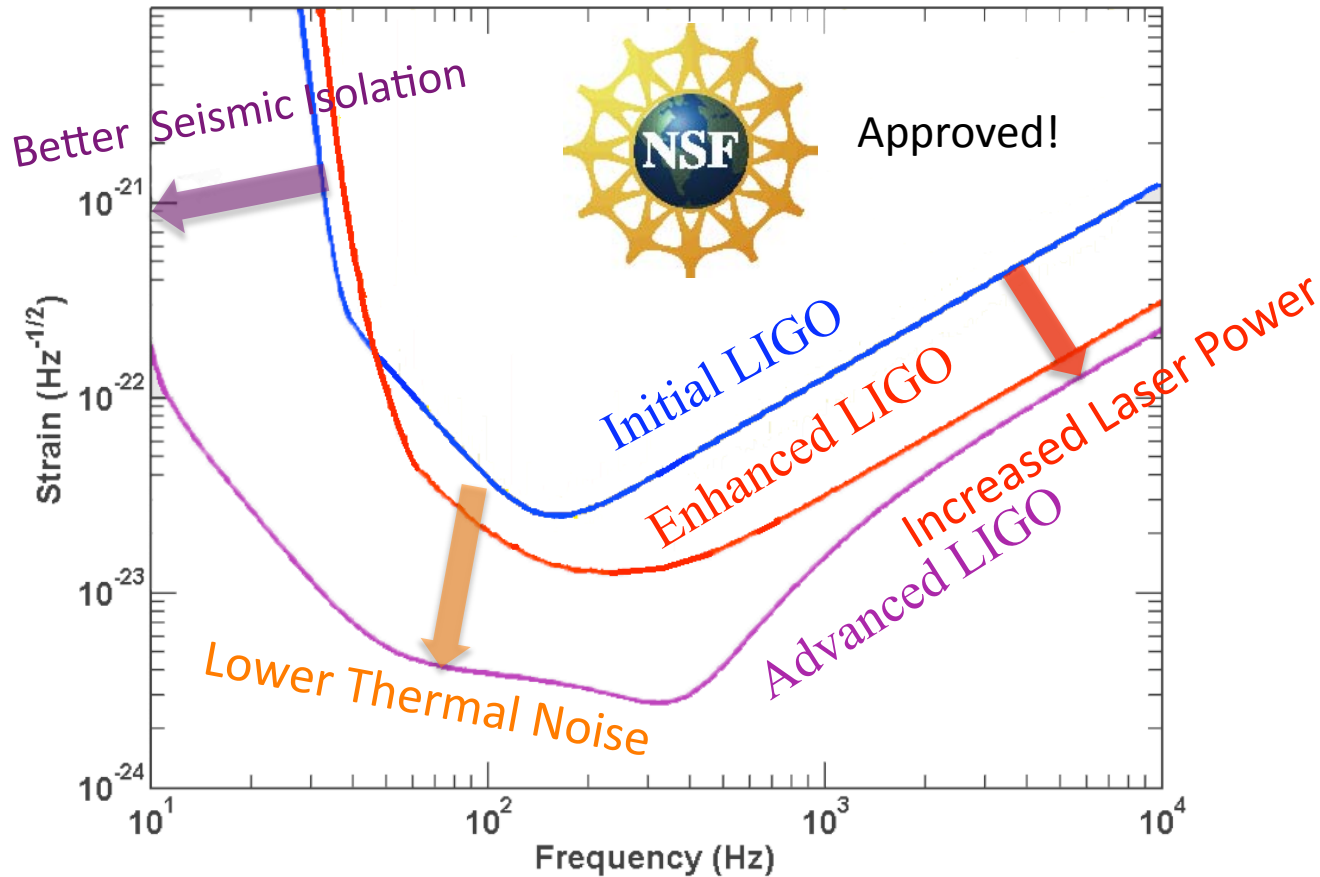


# Strain Sensitivity and Fundamental Noise Sources





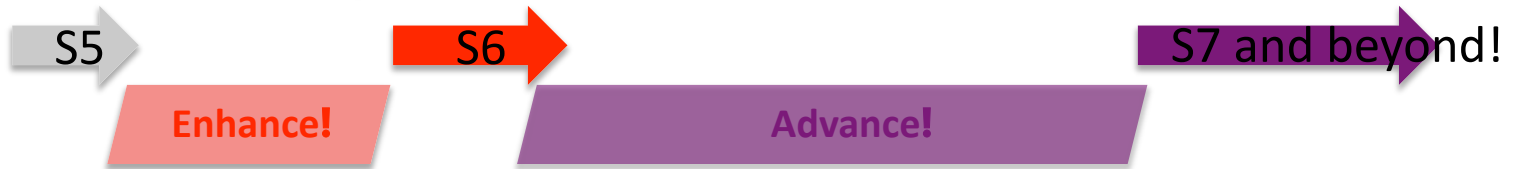
# Projected Future Strain Sensitivity



5'

2007 2008 2009 2010 2011 2012 2013 2014 2015

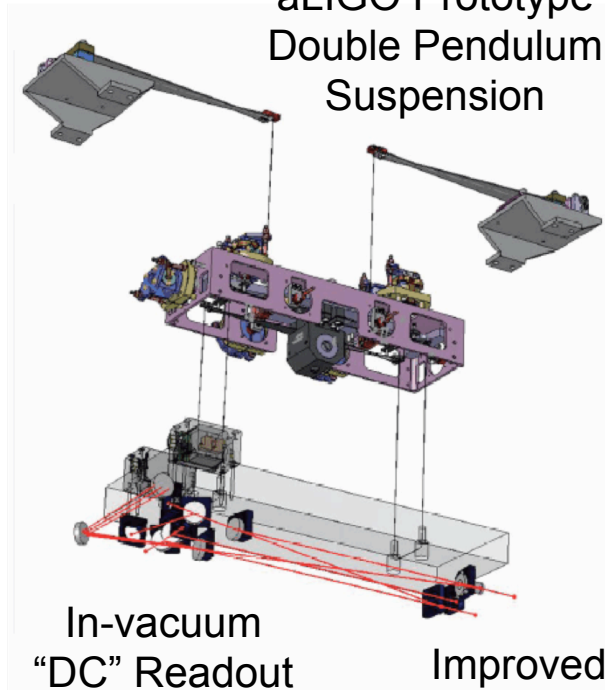
Observing  
Upgrading





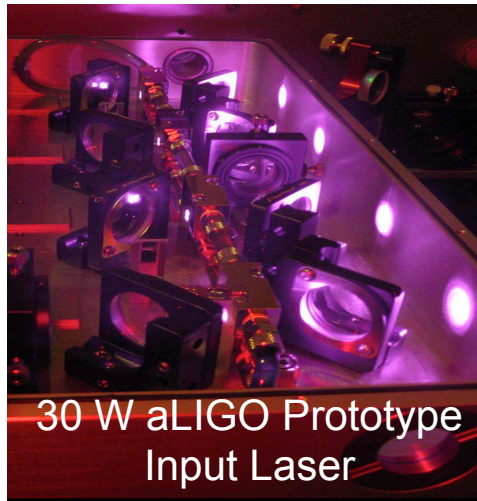
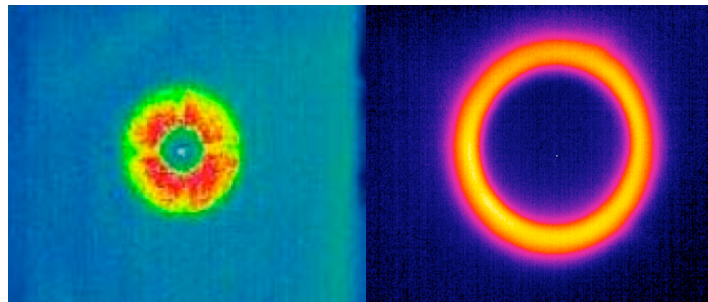
## “Minor” Upgrades to the two 4 km interferometers

aLIGO Prototype  
Double Pendulum  
Suspension

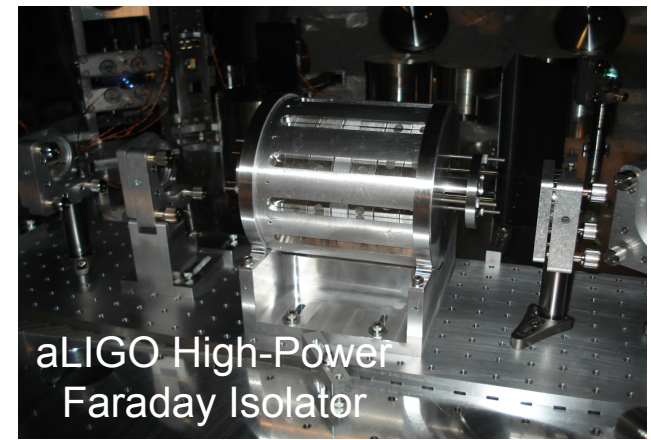


In-vacuum  
“DC” Readout  
Photo Diodes and  
Output Mode  
Cleaner

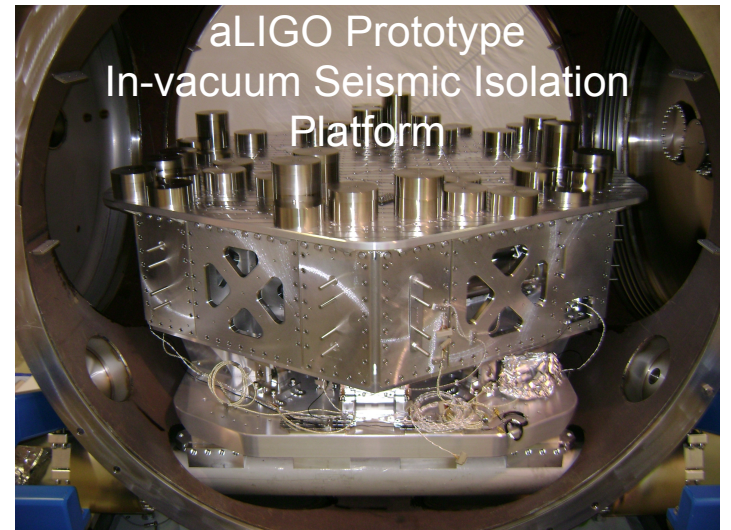
Improved, High Power Thermal  
Compensation System



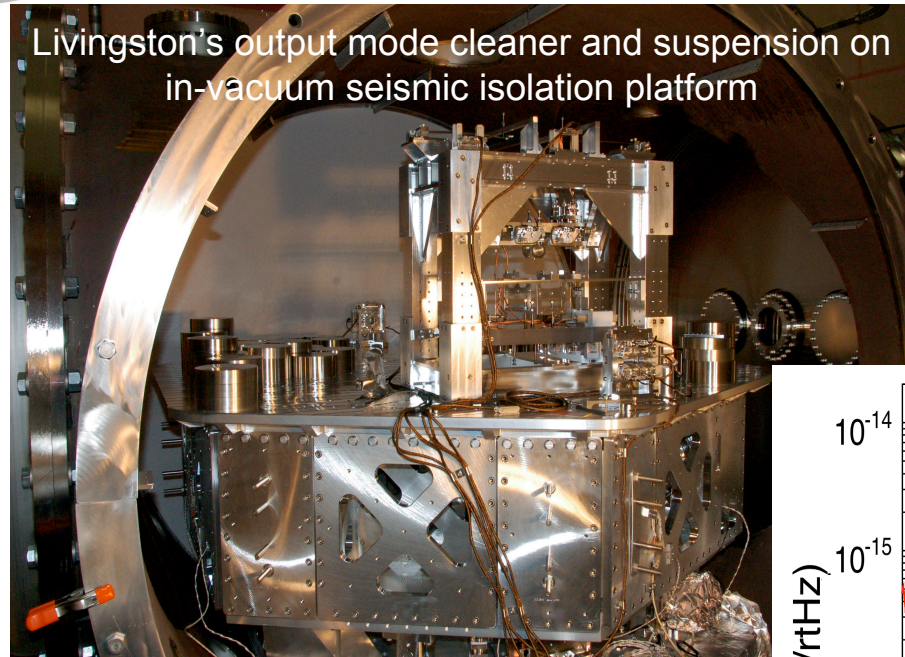
30 W aLIGO Prototype  
Input Laser



aLIGO High-Power  
Faraday Isolator



aLIGO Prototype  
In-vacuum Seismic Isolation  
Platform

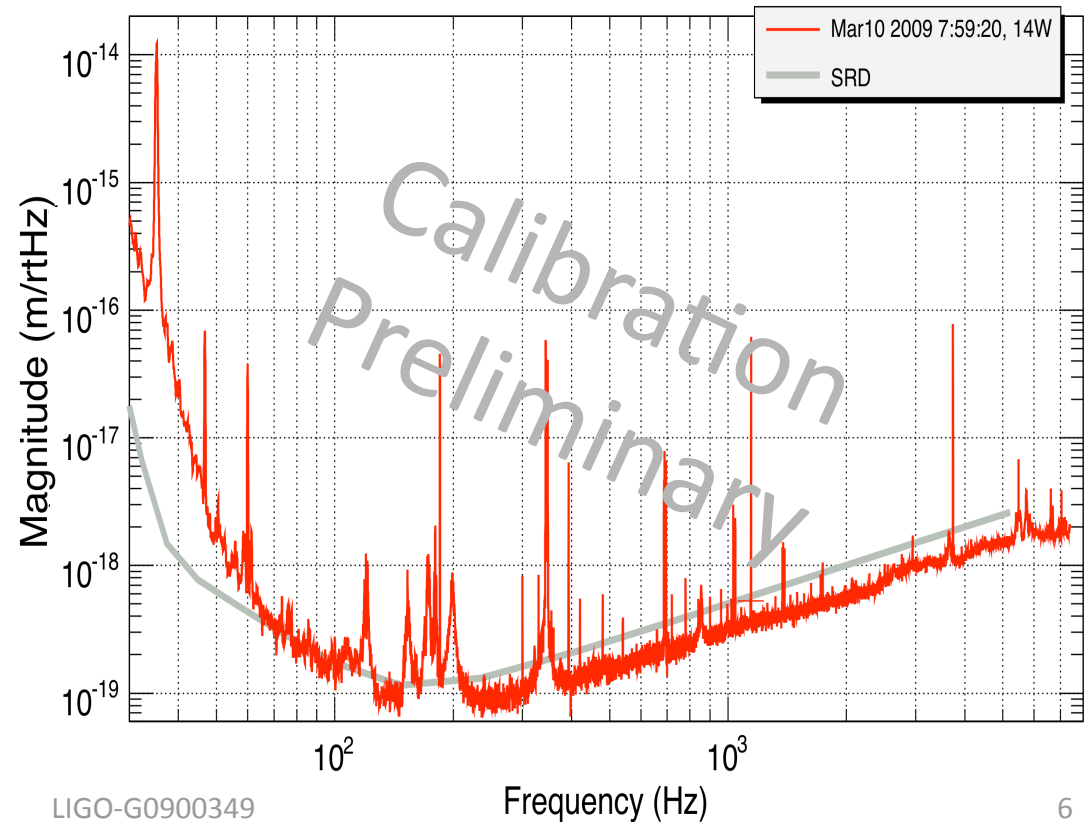


Livingston's output mode cleaner and suspension on in-vacuum seismic isolation platform

## Almost there!

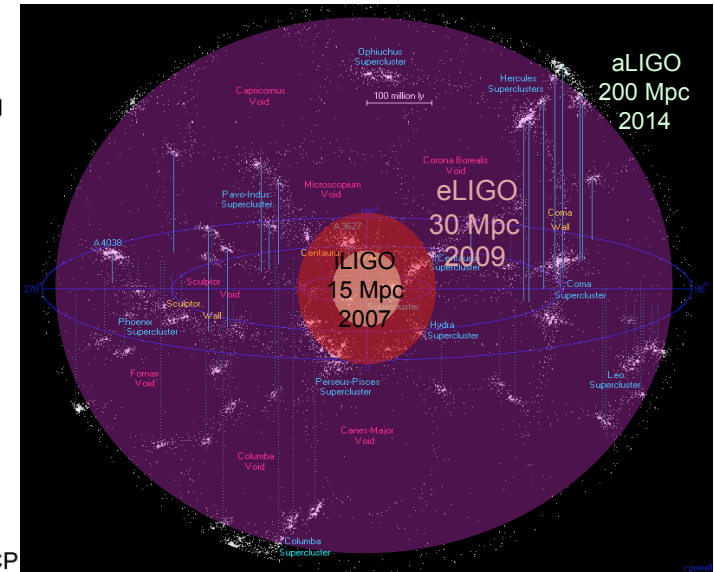
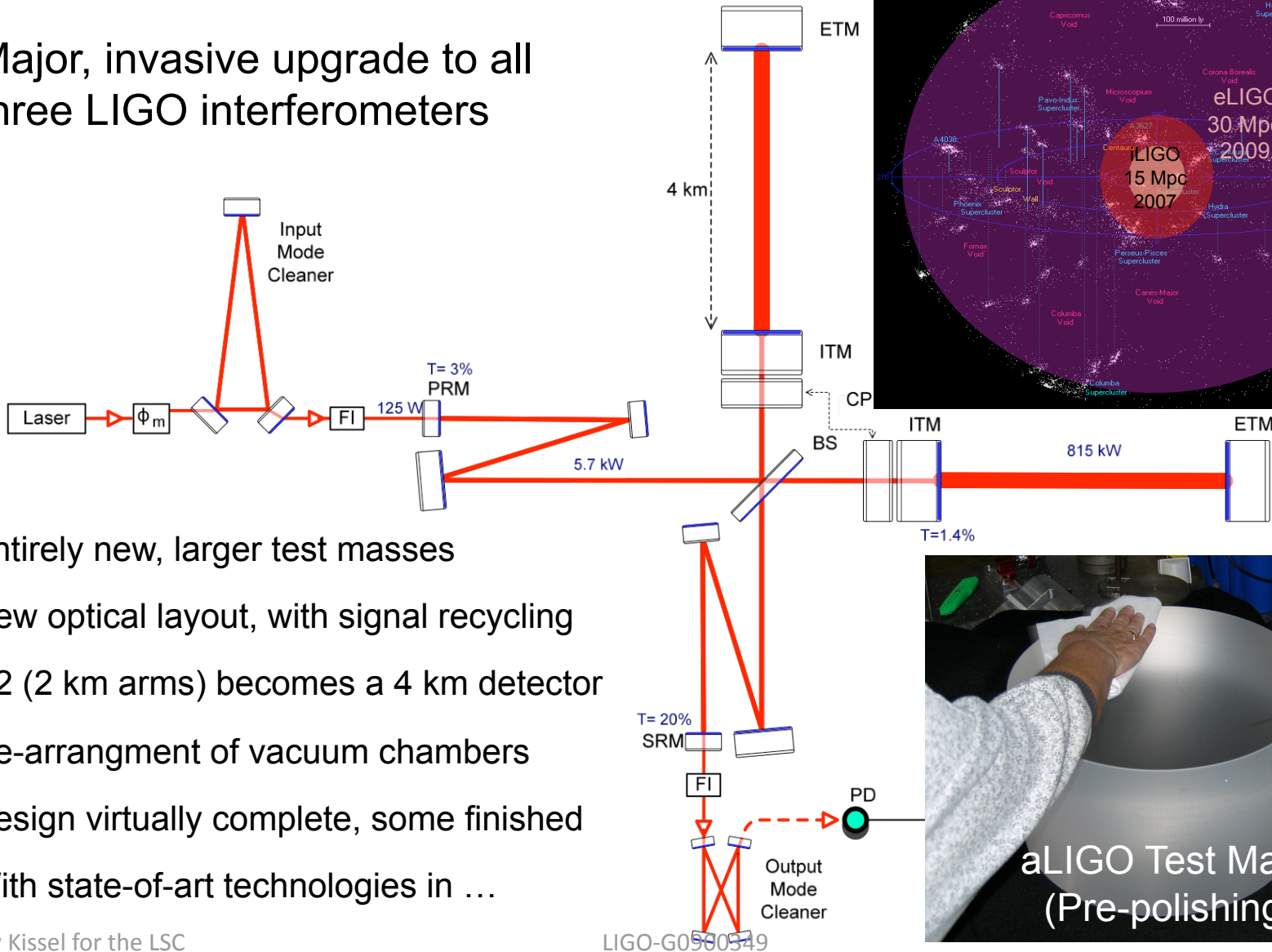
- Installation of all in-vacuum hardware is complete for both interferometers in July 2008
- “First light” in August 2008

- Both are already close if not beating Initial LIGO's sensitivity at high frequency
- Noise hunting or “commissioning” until S6
- S6 is only months away!





Major, invasive upgrade to all three LIGO interferometers



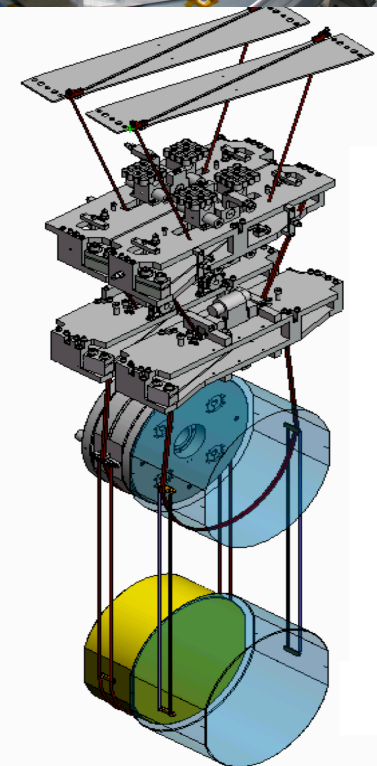
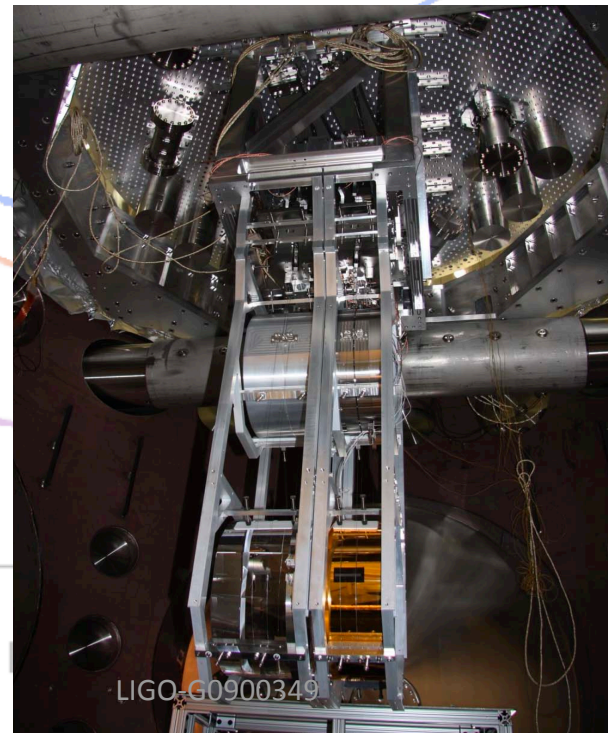
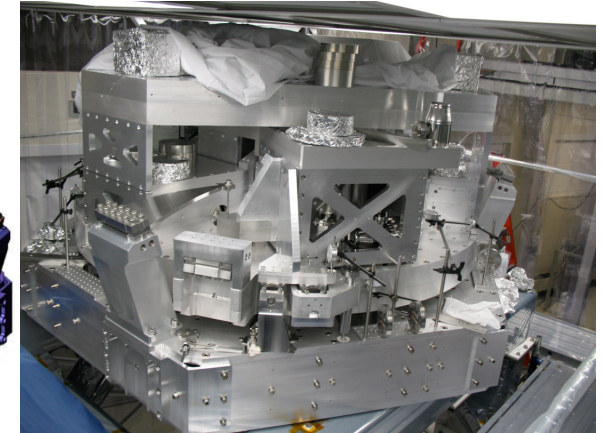
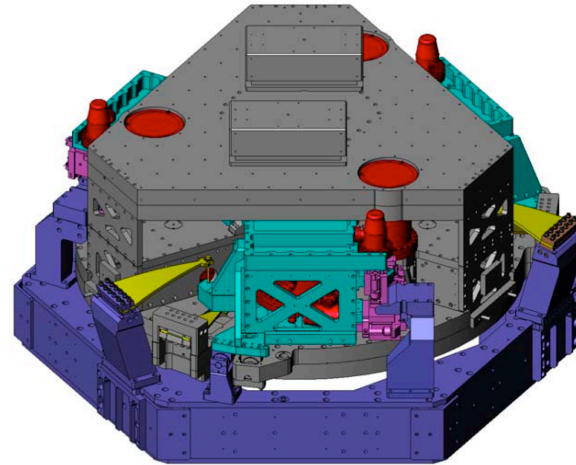
- Entirely new, larger test masses
- New optical layout, with signal recycling
- H2 (2 km arms) becomes a 4 km detector
- Re-arrangement of vacuum chambers
- Design virtually complete, some finished
- With state-of-art technologies in ...

Better Seismic Isolation

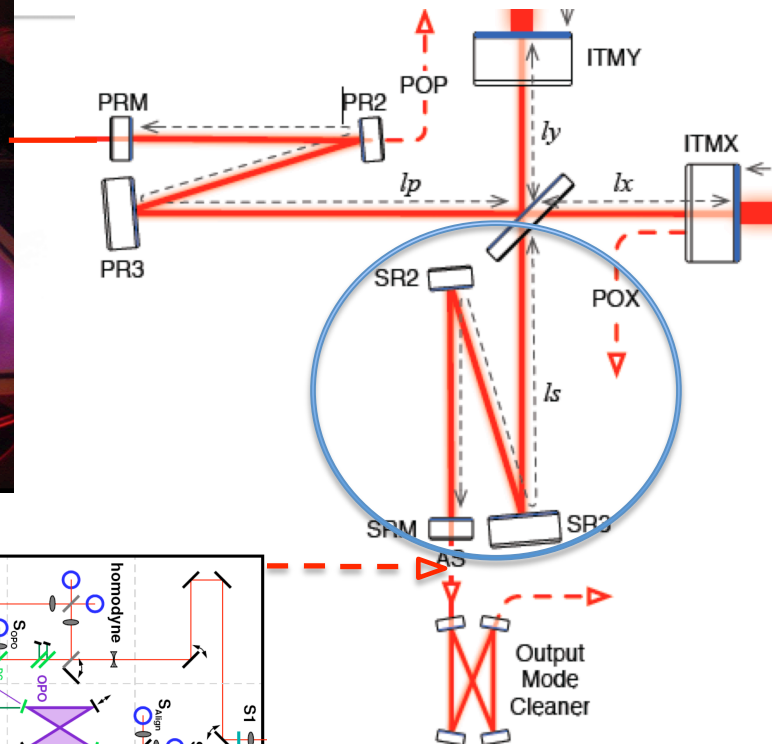
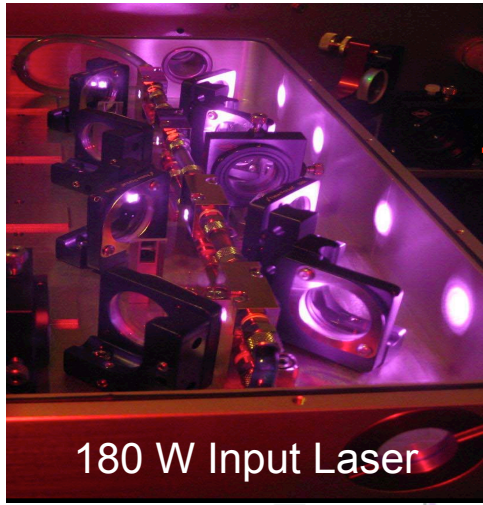
The core optics get:

- Active seismic isolation on External Support System (not shown)
- Double Stage Active In-vacuum Seismic Isolation platform
- Quadruple Pendulum Suspension, with monolithic fused silica wires

To get a factor of  $10^6$  (at 10 Hz) in isolation from ground motion

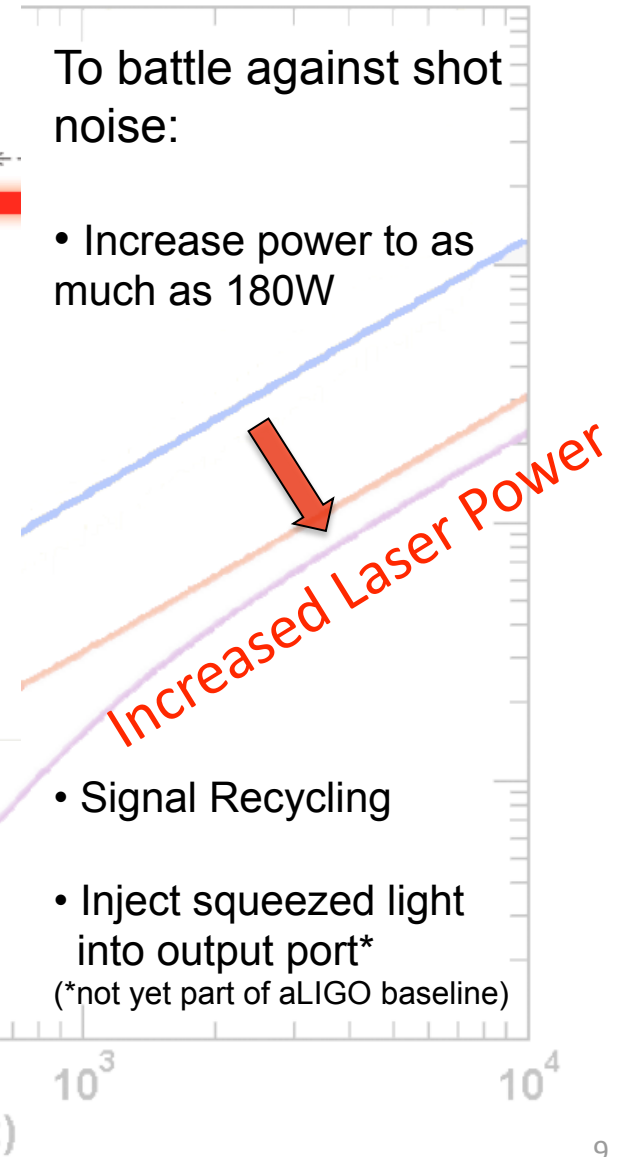






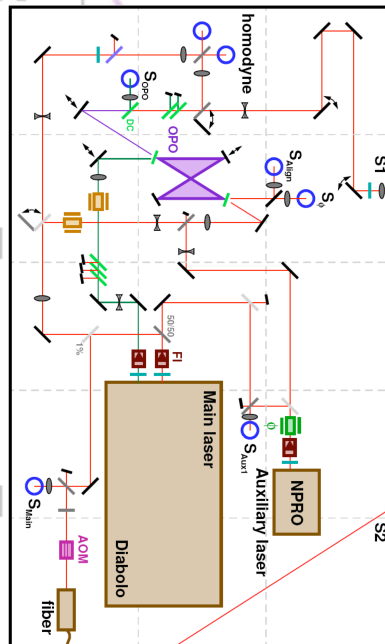
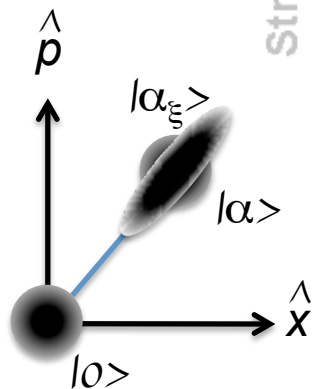
To battle against shot noise:

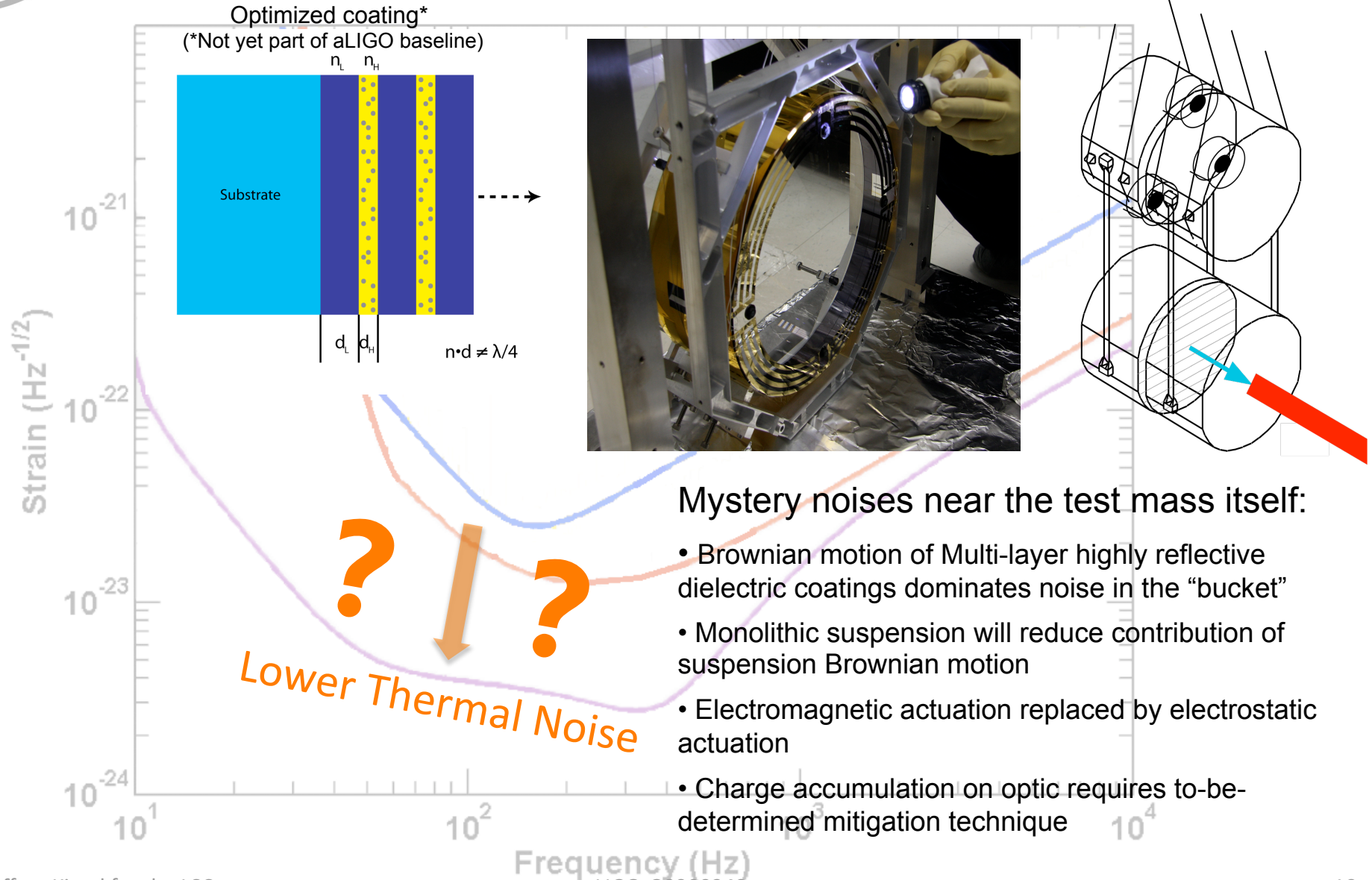
- Increase power to as much as 180W



- Signal Recycling

- Inject squeezed light into output port\* (\*not yet part of aLIGO baseline)

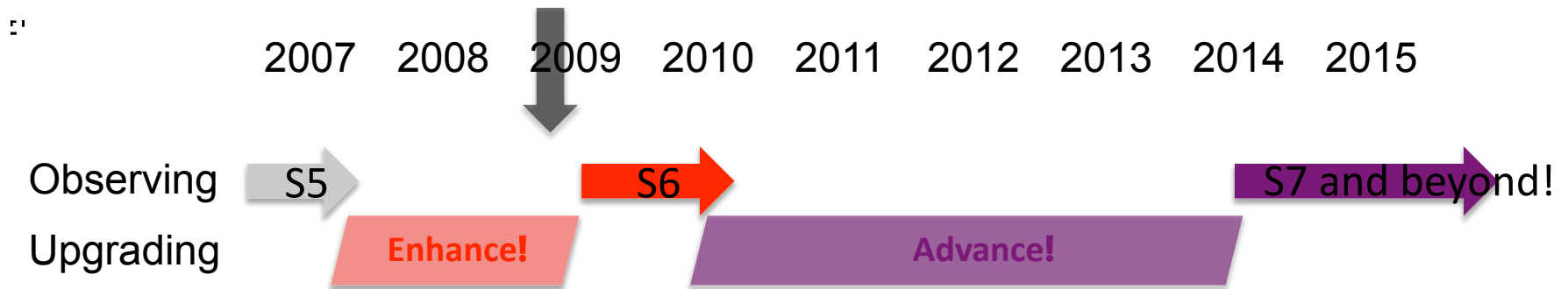








# The Present and Near Future!



- All **Enhanced LIGO** upgrades are installed/finished
- Spectrum is at **S5** level, noise-hunting efforts are at full steam
- Only months away from **S6**!
- **Advanced LIGO** prototypes in **Enhanced LIGO** a success
- Lots of **Advanced LIGO** hardware completed final design stages, some already purchased and beginning assembly
- Still some serious **Advanced LIGO** issues to resolve, but...

**The future is near, and it looks bright!**

Gravitational waves.... here we come!

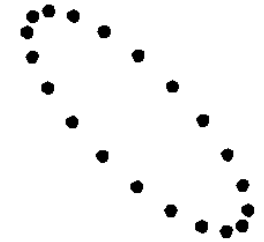




# Gravitational Waves and Astrophysical Sources



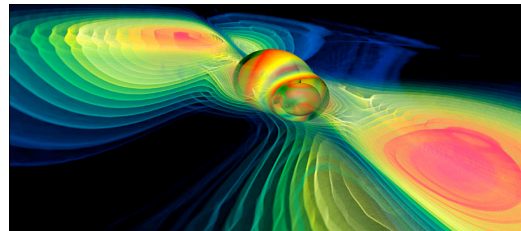
- General relativity predicts the existence of gravitational waves
- Produce quadrupolar strain  $h$  on space-time
- Astrophysical sources include



Burst from Supernova / Unmodeled Sources



Continuous from Non-Spherical Rotating Sources



Short Duration from compact binaries coalescence



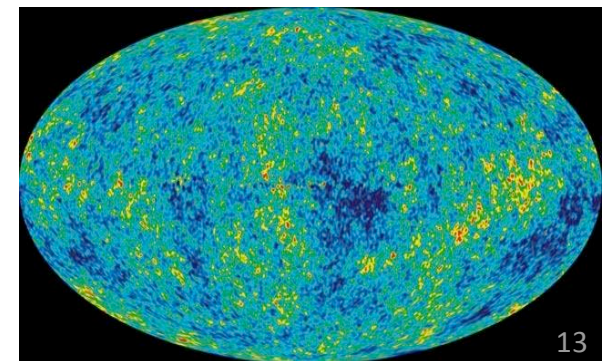
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Image: NASA/GSFC/D. Berry

$$h_{CBC}^{\oplus} = \frac{\Delta L}{L} \approx 10^{-21}$$

LIGO-G0900349

Stochastic Background







# Basic Observation of Gravitational Waves

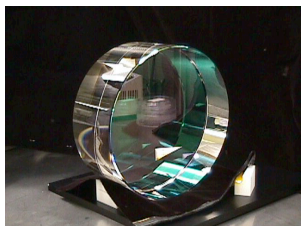
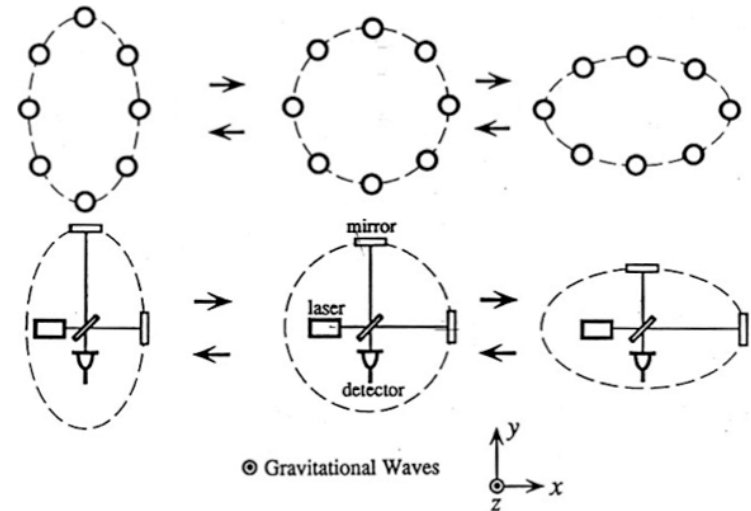


- Can detect strain using Michelson interferometer

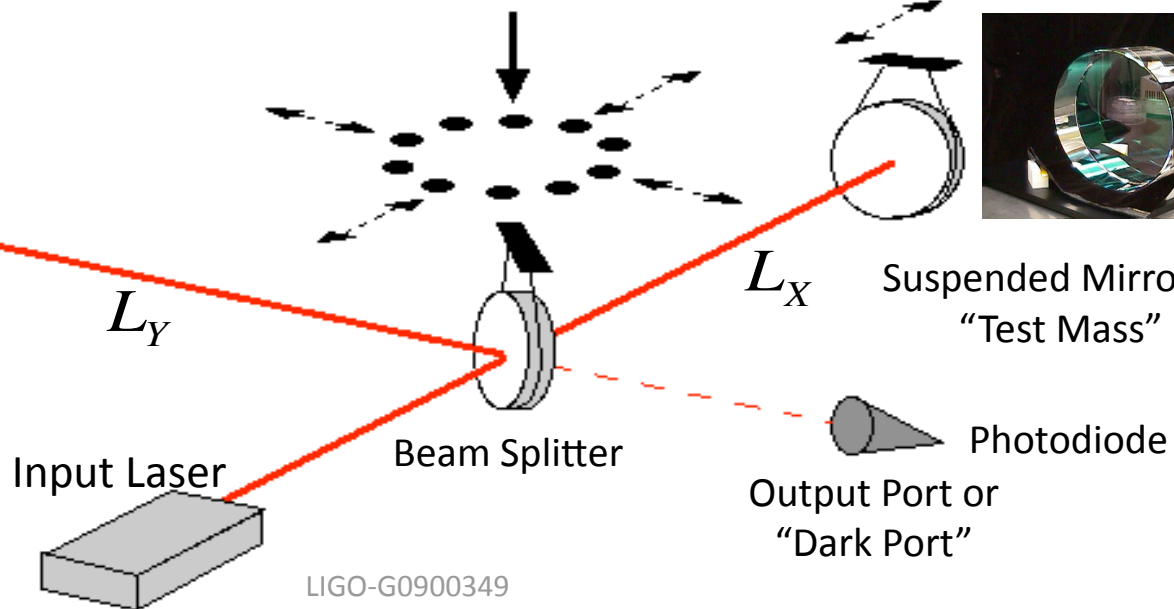
$$\Delta L = L_X - L_Y = h L$$

- Suspended Mirrors act as inertial particles
- If Michelson arms are 1 km long,

$$\Delta L = h_{CBC}^{\oplus} L_{km} = 10^{-18} m$$



Suspended Mirror or "Test Mass"



Suspended Mirror or "Test Mass"

Photodiode  
Output Port or "Dark Port"



# Projected Volume of Space Covered

