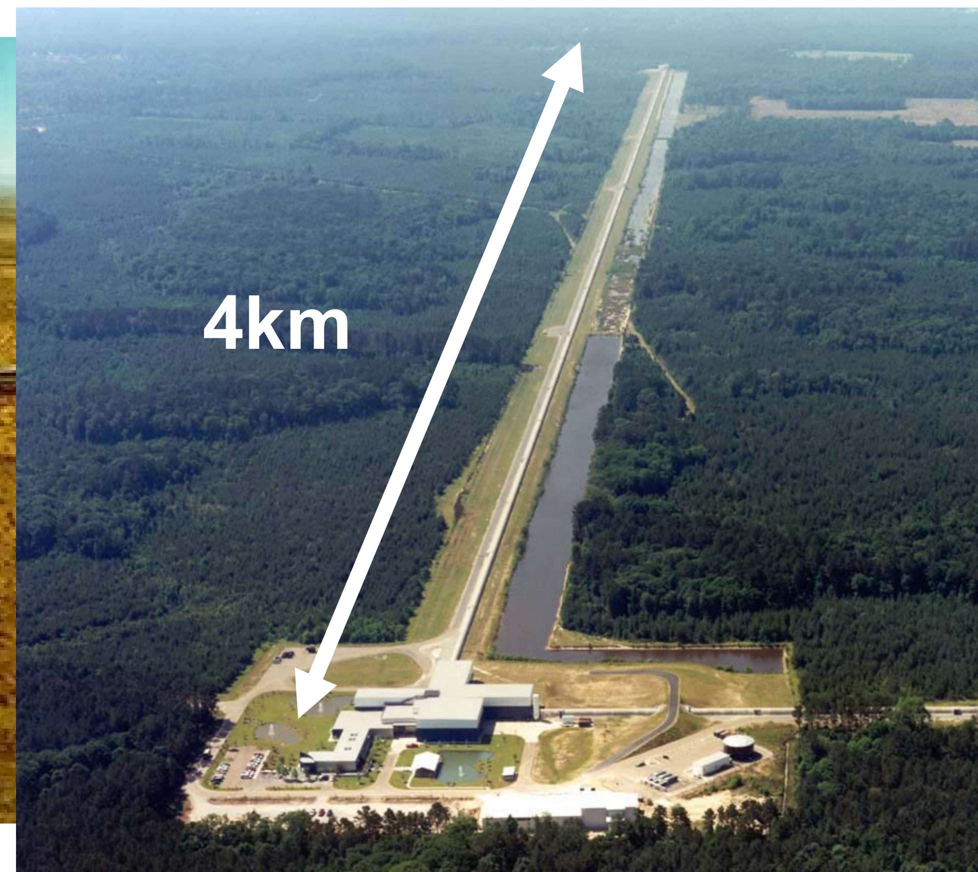
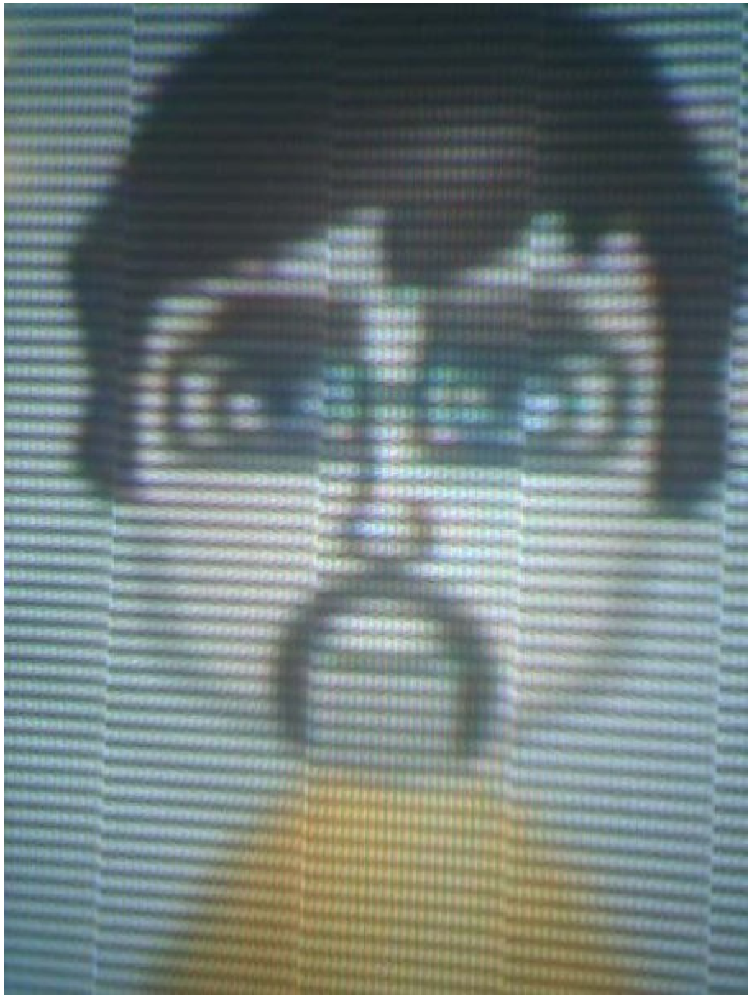
Recent progress and future prospects for LIGO

Nicolas Smith-Lefebvre Dec. 20 2011 ICRR



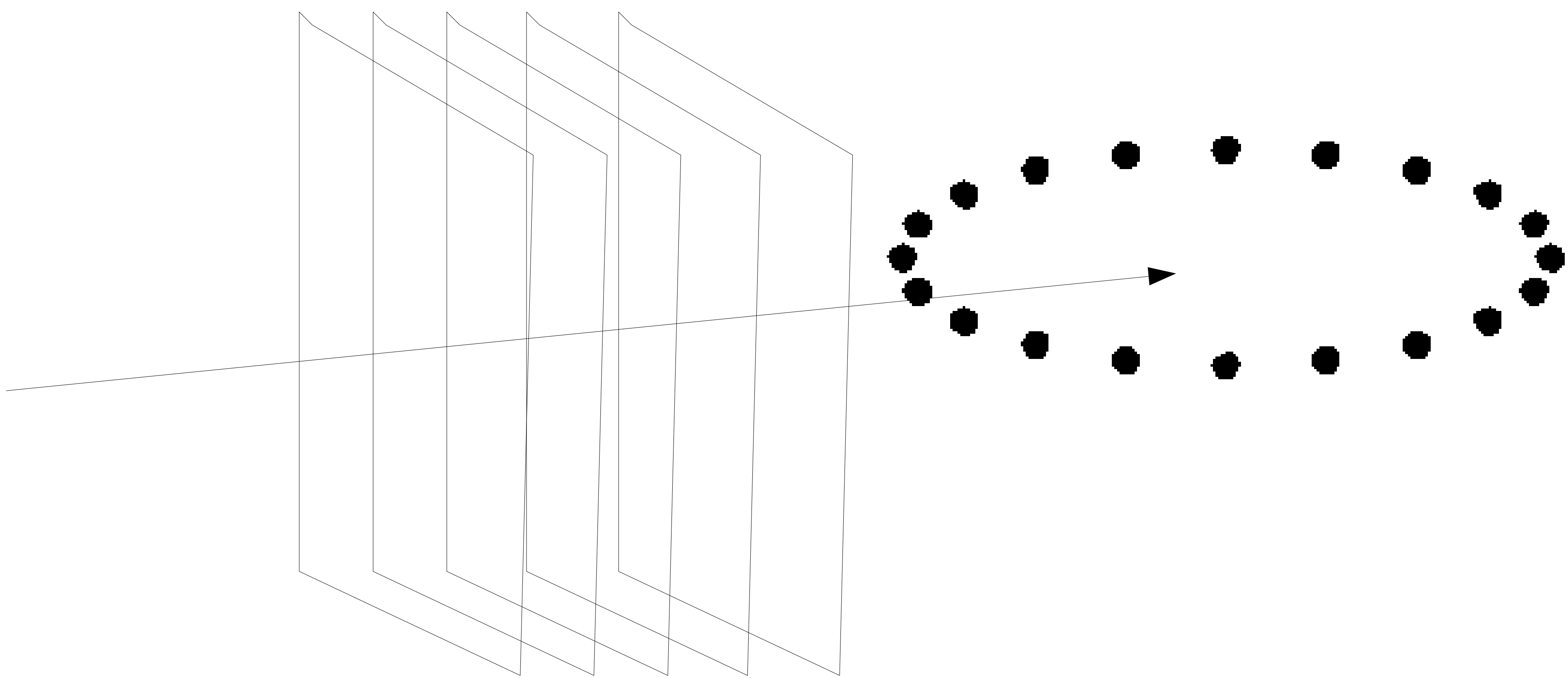
Introduction of myself

- 5.5 years graduate student at MIT
- Started working with LIGO in a summer project in 2005
- Working on the thesis...
- Finishing PhD in the summer

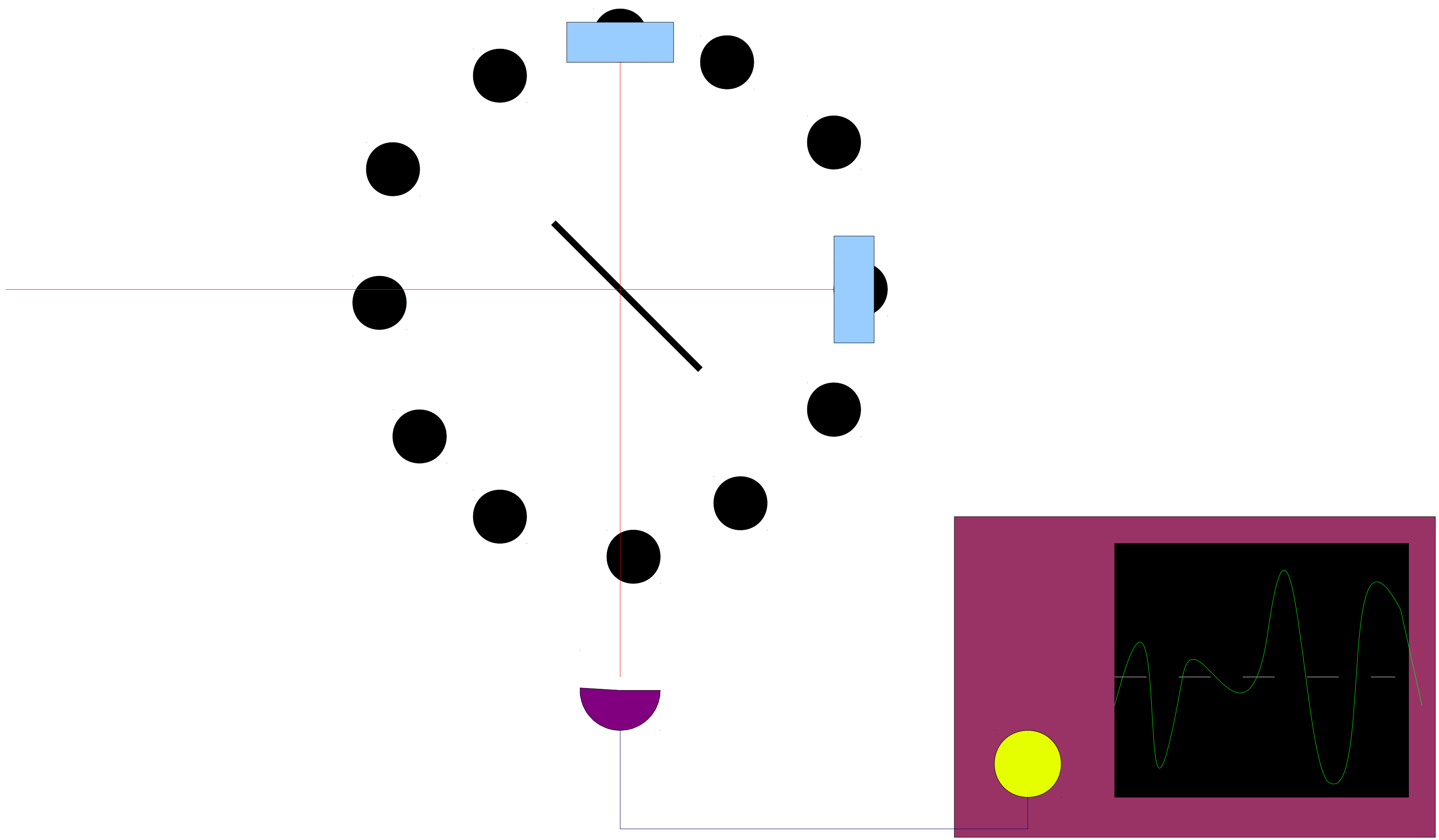


Gravitational Waves

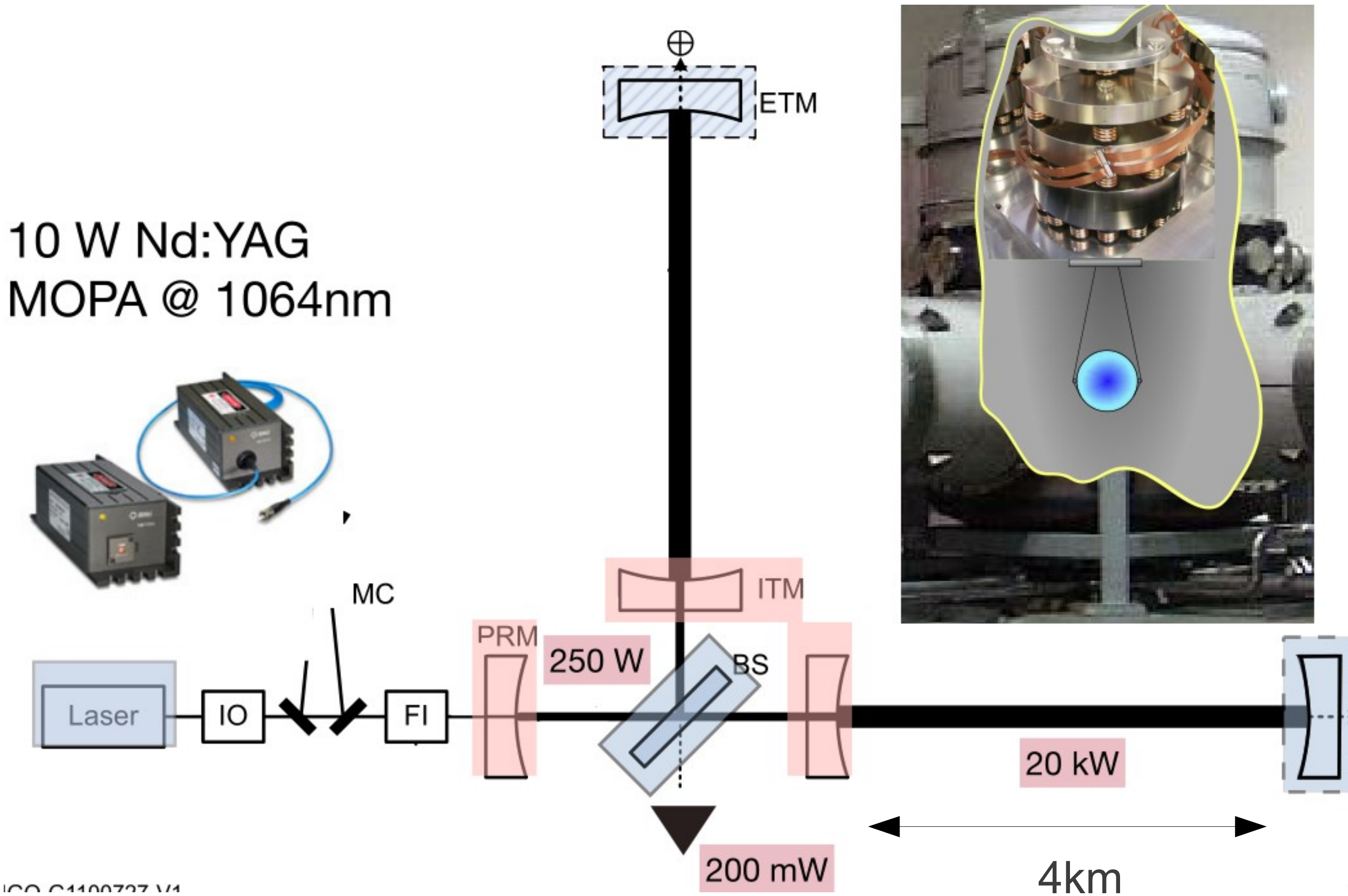
$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$



GW detection using a Michelson interferometer



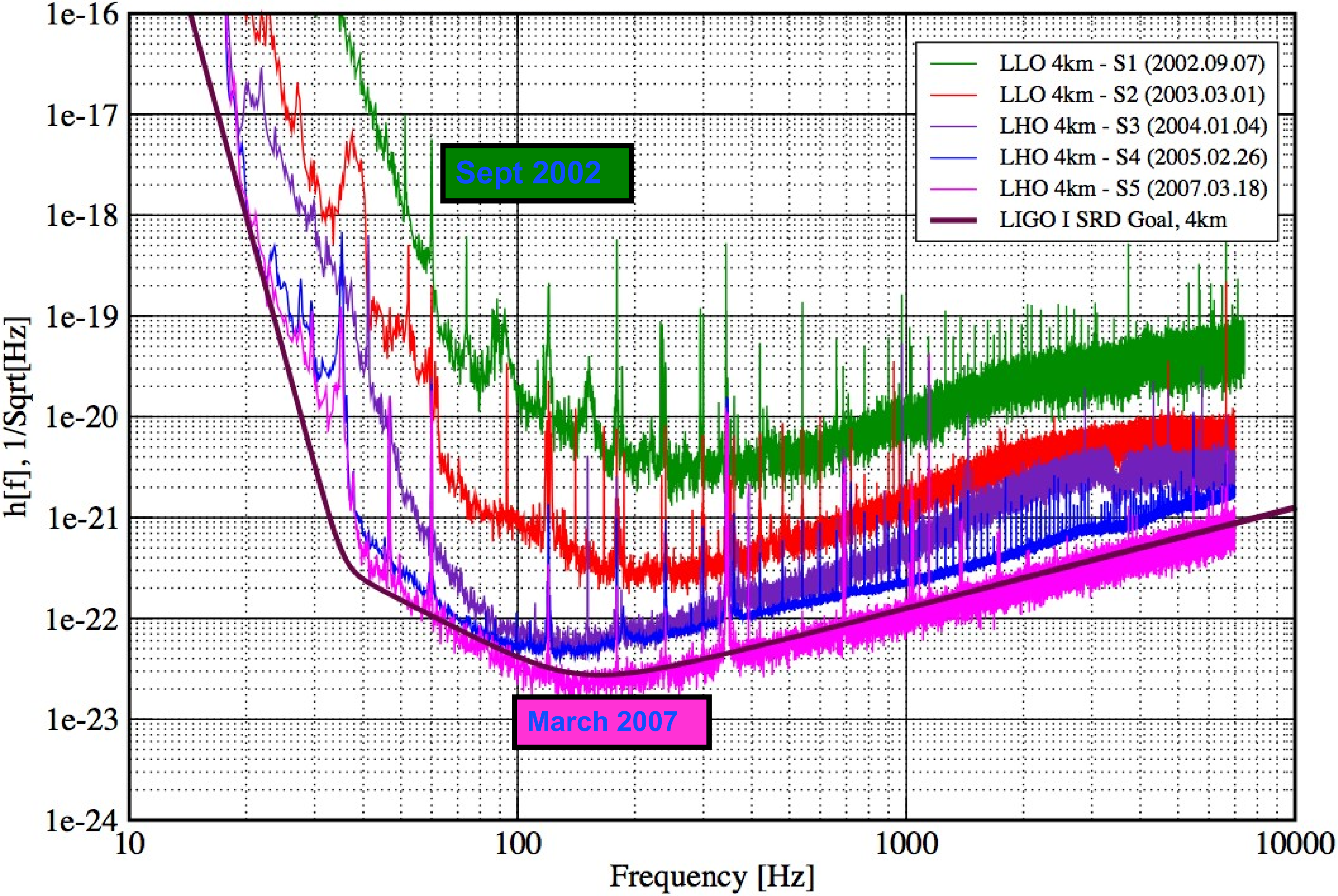
LIGO Basics



- 3 interferometers, Two sites
- Run by MIT and Caltech
- Large international collaboration (LSC)

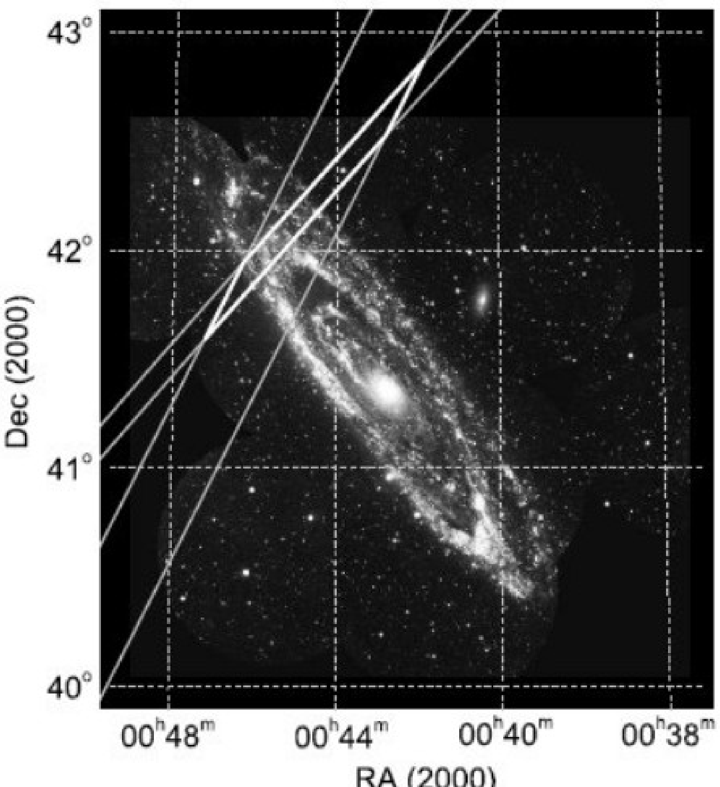
Best Strain Sensitivities for the LIGO Interferometers

Comparisons among S1 - S5 Runs LIGO-G060009-03-Z



Science by non-detection

- Crab pulsar spindown
- GRB070201
- Primordial GWs, compared to BBN limit
- Rates of binary mergers

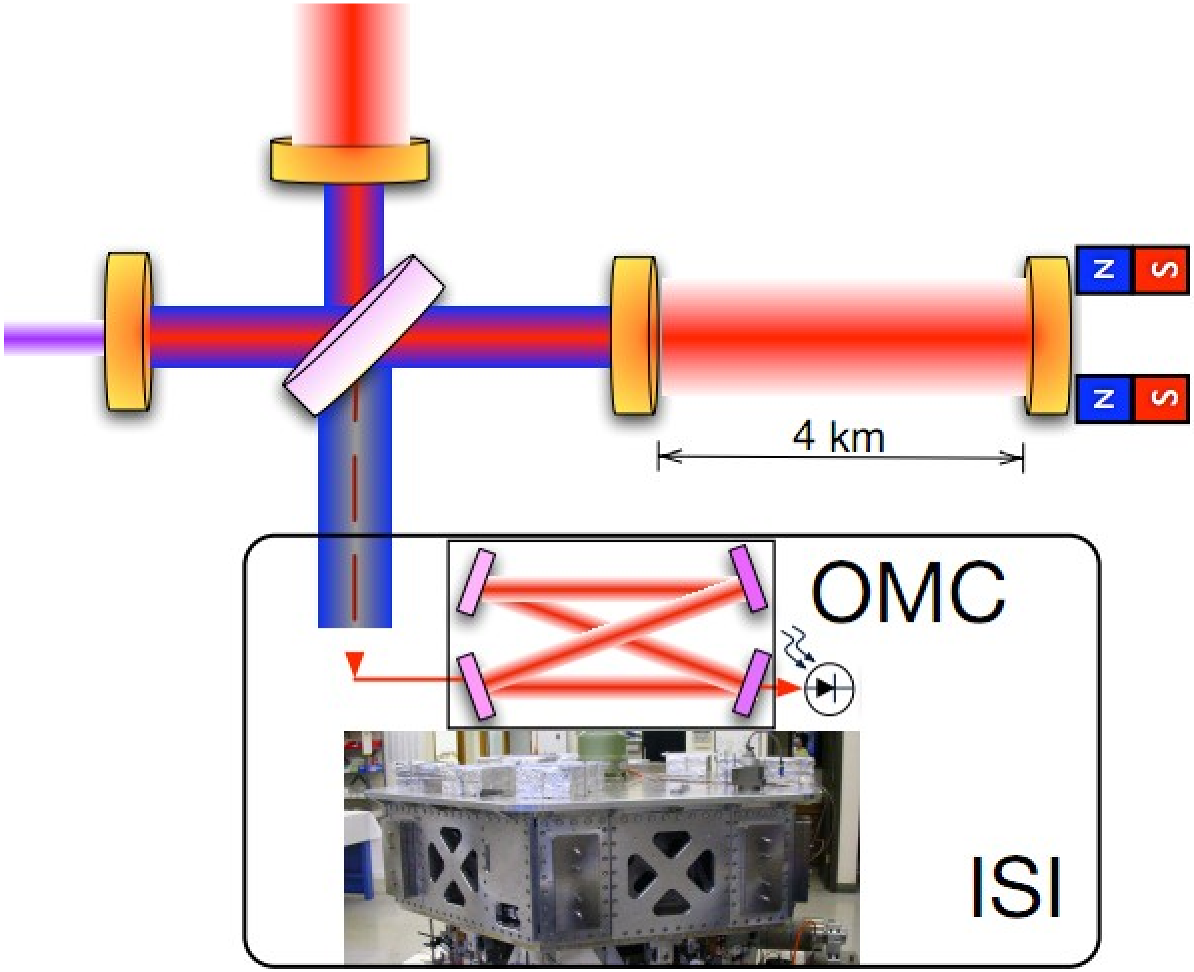


Enhanced LIGO

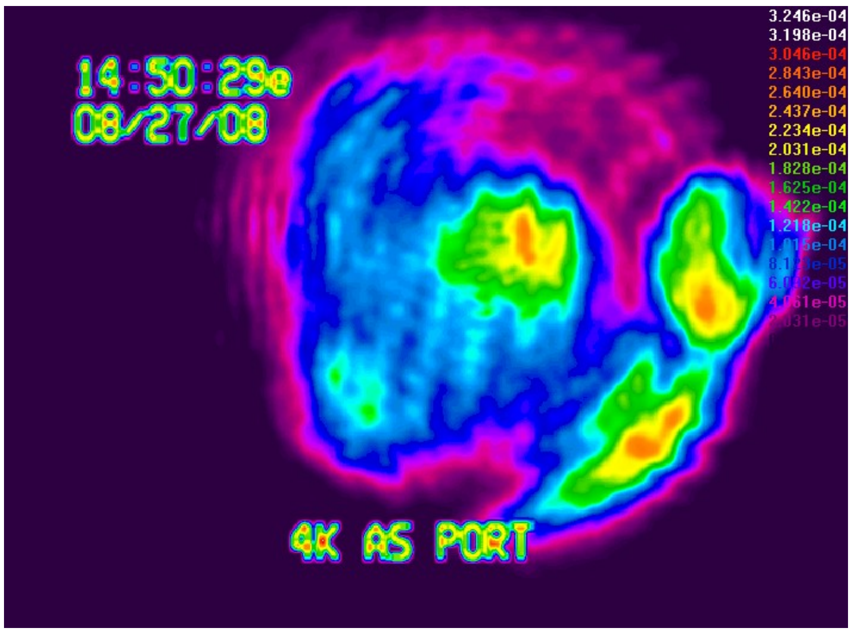
- Make improvements to Initial LIGO detectors using Advanced LIGO technology
  - New Laser
  - Output Mode Cleaner
  - DC Readout
- I lived on site for 1.5 years in 2008-2009, installing, commissioning

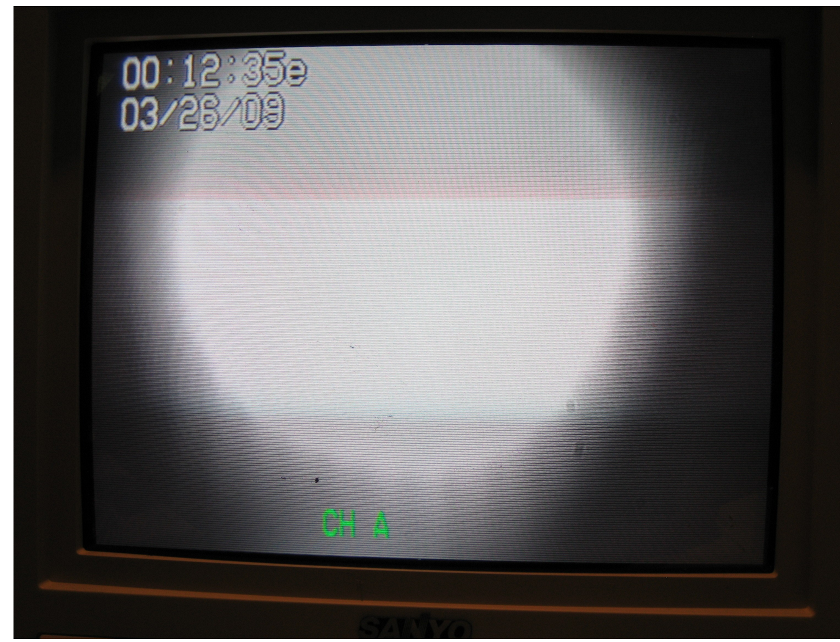
The Output Mode Cleaner (OMC)

- Filters the light coming out of the interferometer



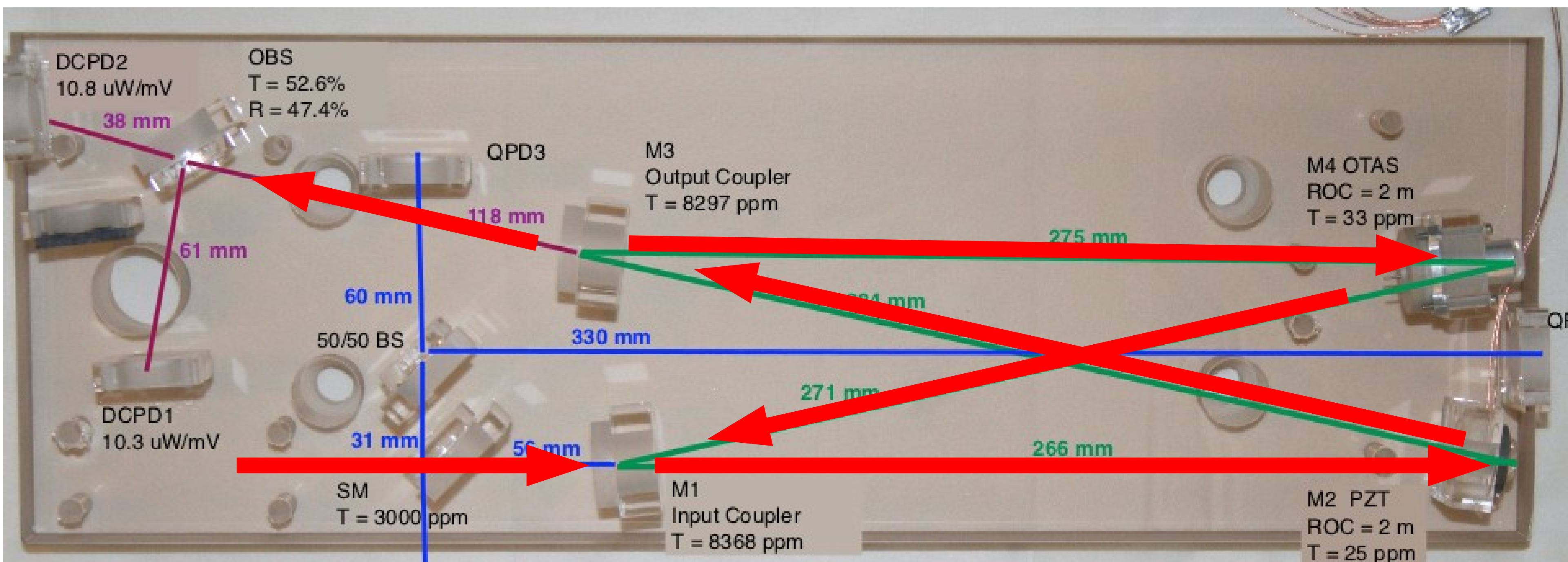
The goal of the OMC



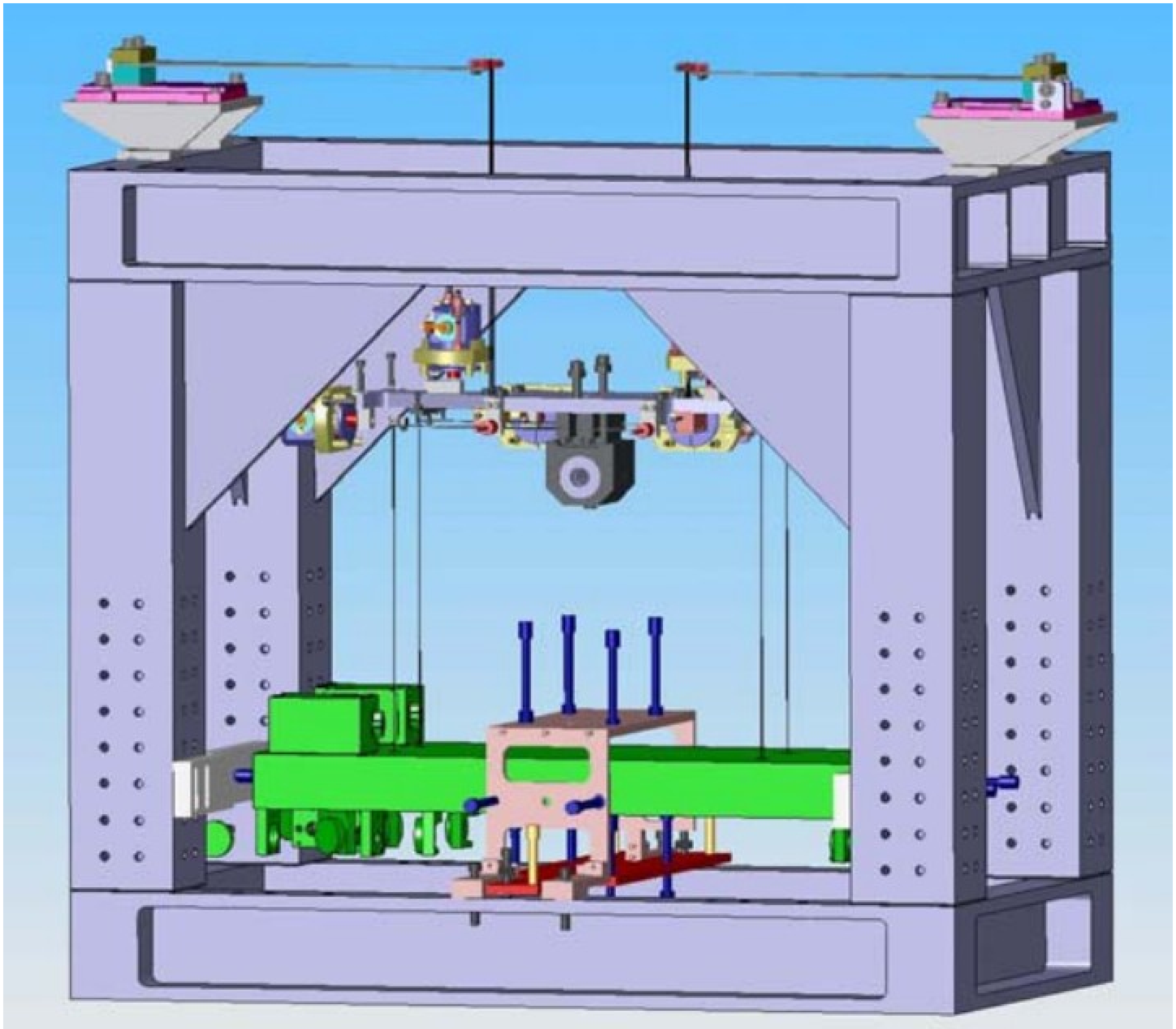


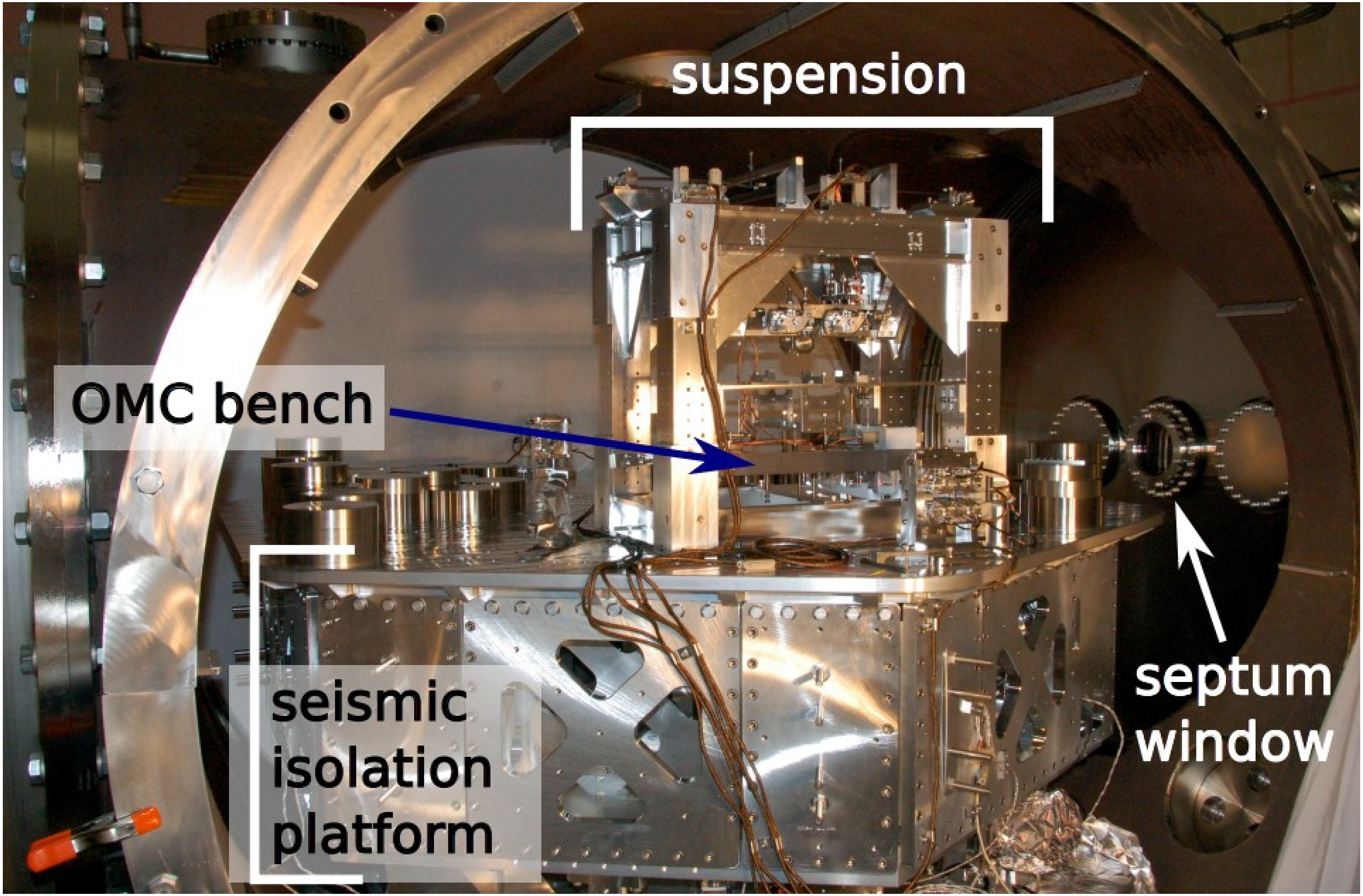
Up close with the OMC

- 4 mirror cavity, ~1m length
- Finesse ~370
- Length actuators: fast PZT and slow thermal

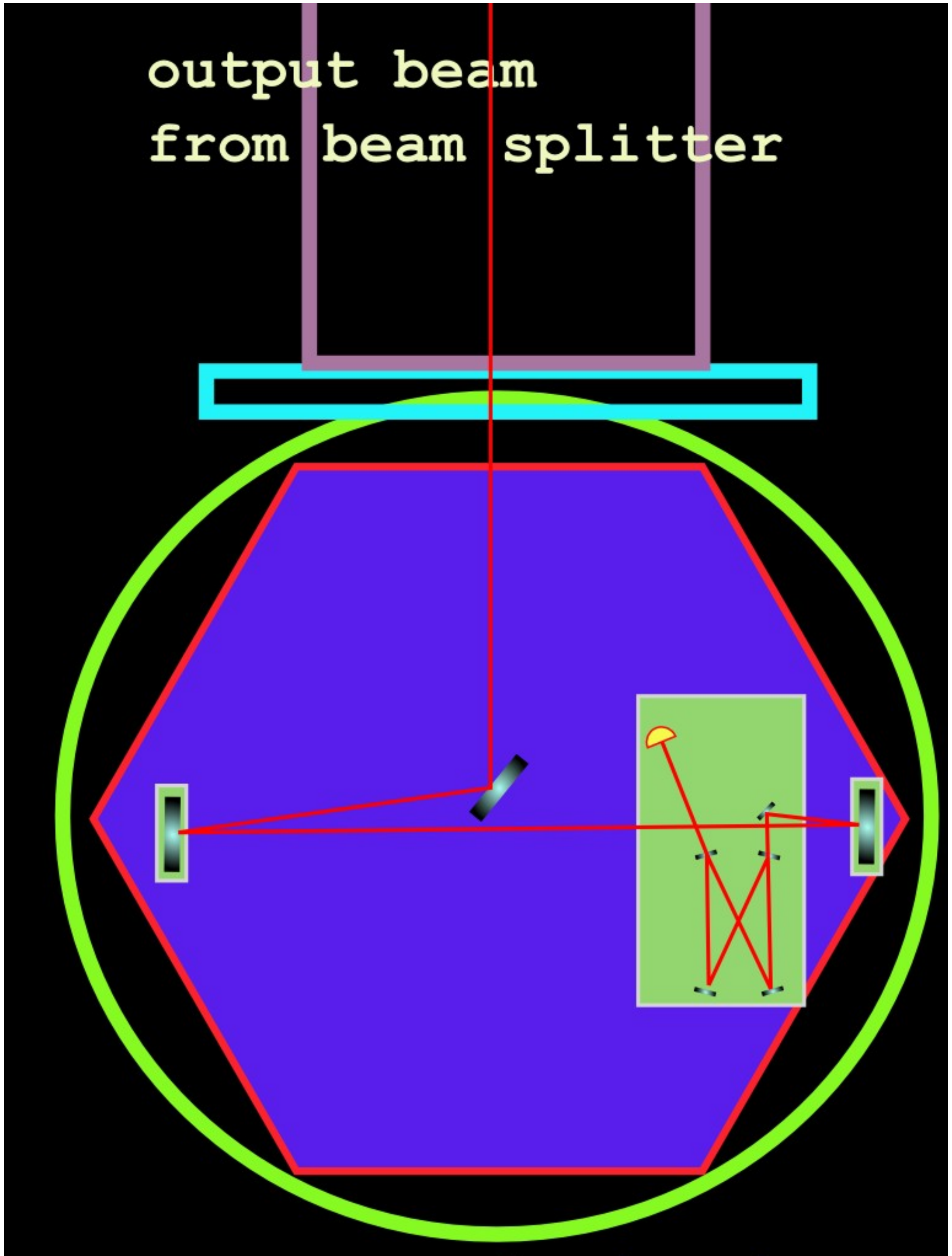


OMC Suspension



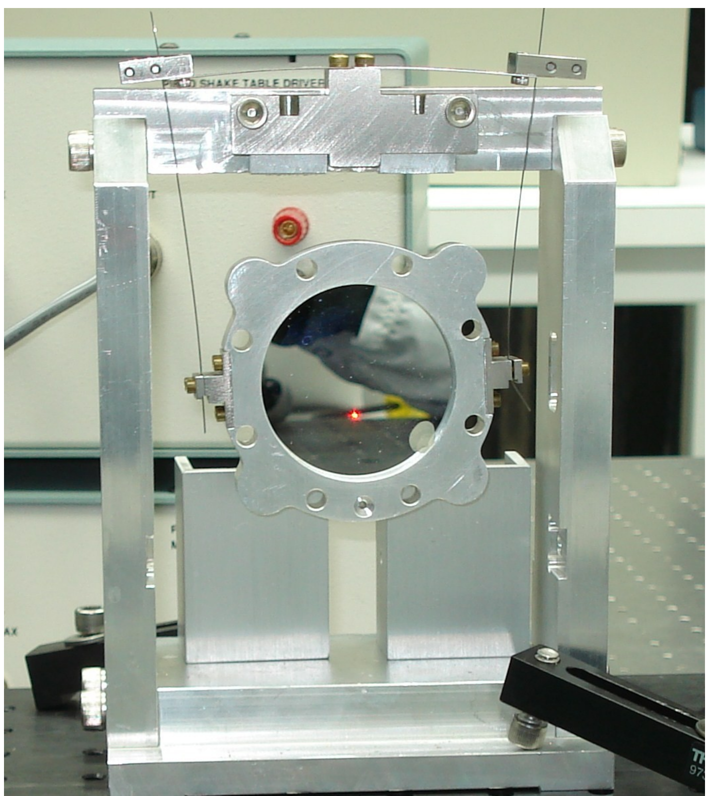

suspension
OMC bench
septum
window
seismic
isolation
platform

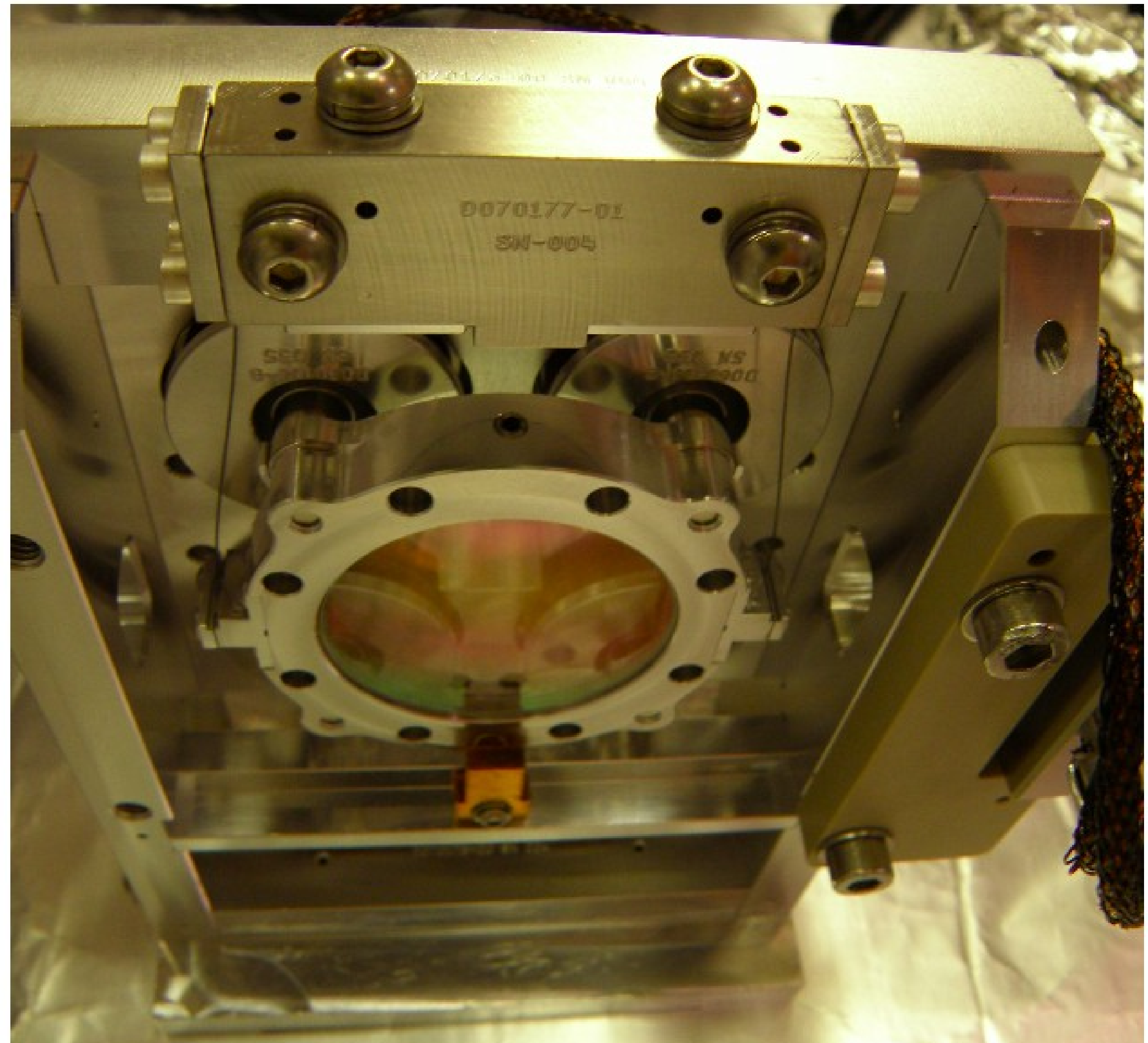
OMC automatic alignment



Tip tilt mirrors

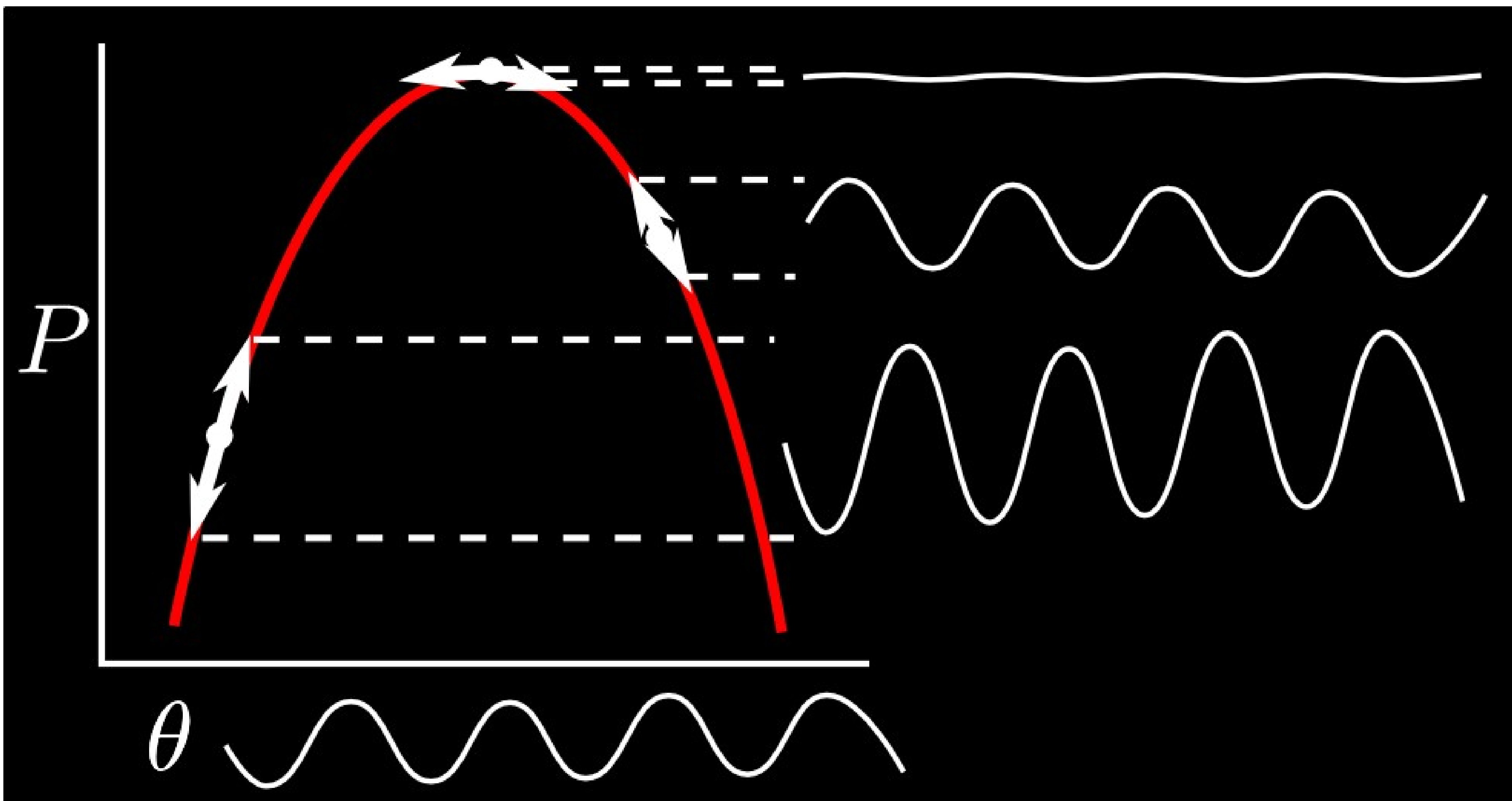
- Single stage pendulum
- Magnetic actuators
- Important lessons learned about beam jitter





Dither alignment

- Very simple way to maximize transmitted power
- Tip-tilt steering mirror is is dithered in angle



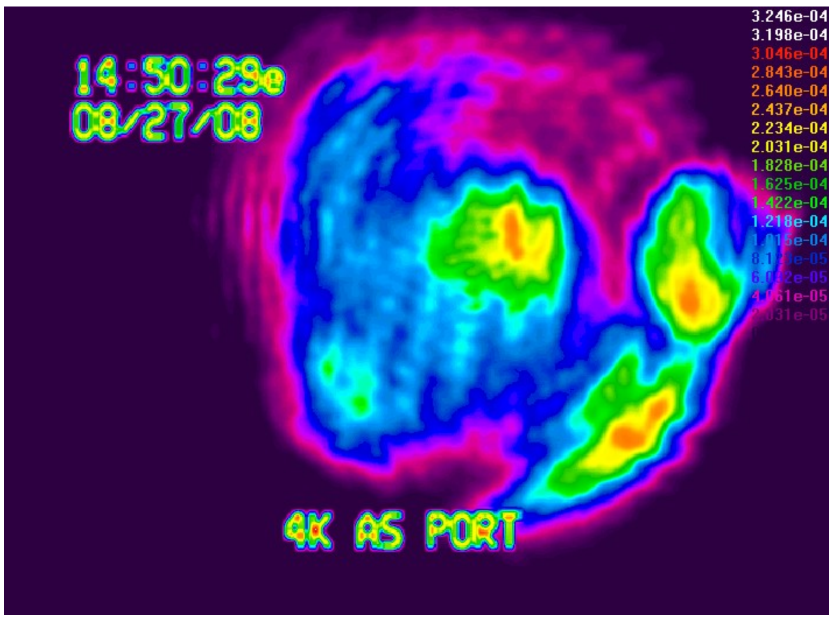
SNR in transmitted signal

- Transmitted signal is composed of carrier and signal audio sidebands
- SNR α audio sideband transmission

$$SNR \propto \frac{cs}{\sqrt{c^2+2s^2}} \approx s$$

- We must maximize the transmission of the sidebands created by the gravitational waves

Dither alignment with a dirty beam



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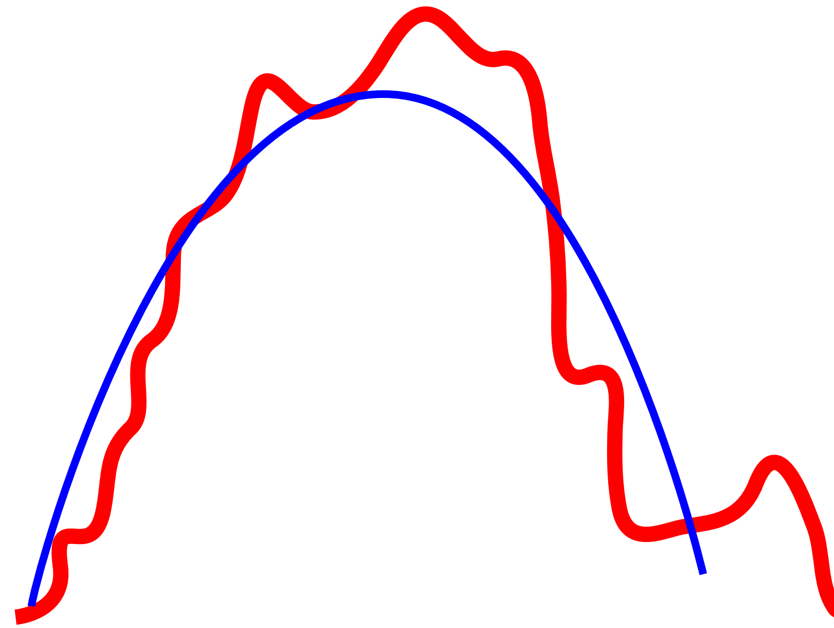


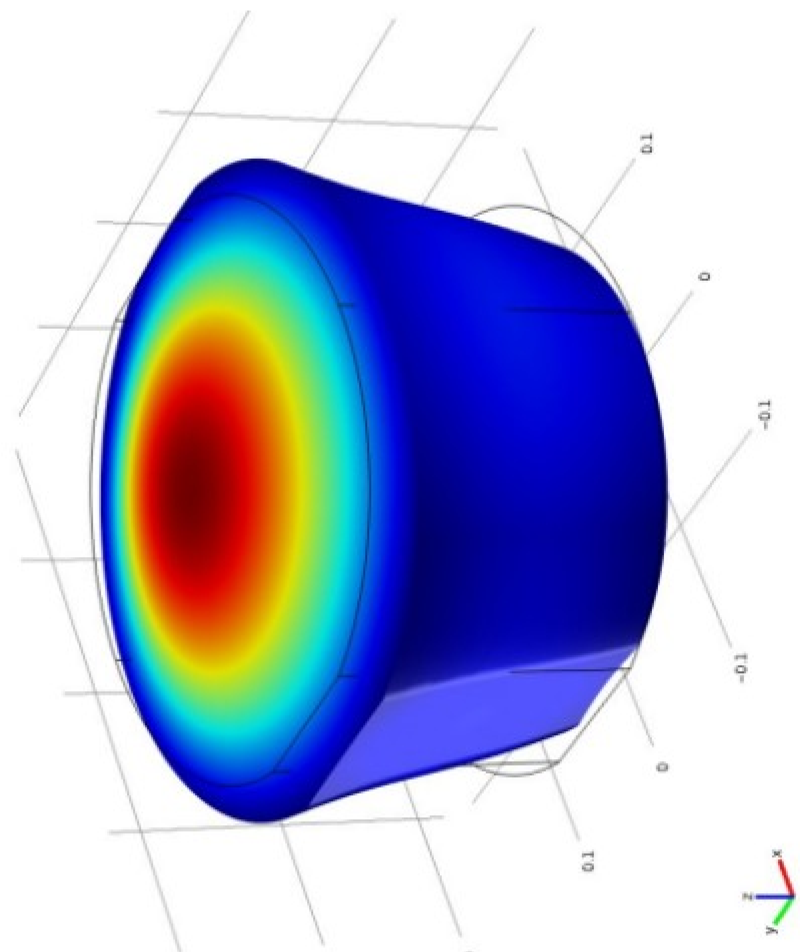
Total Power

Gravitational-wave sideband

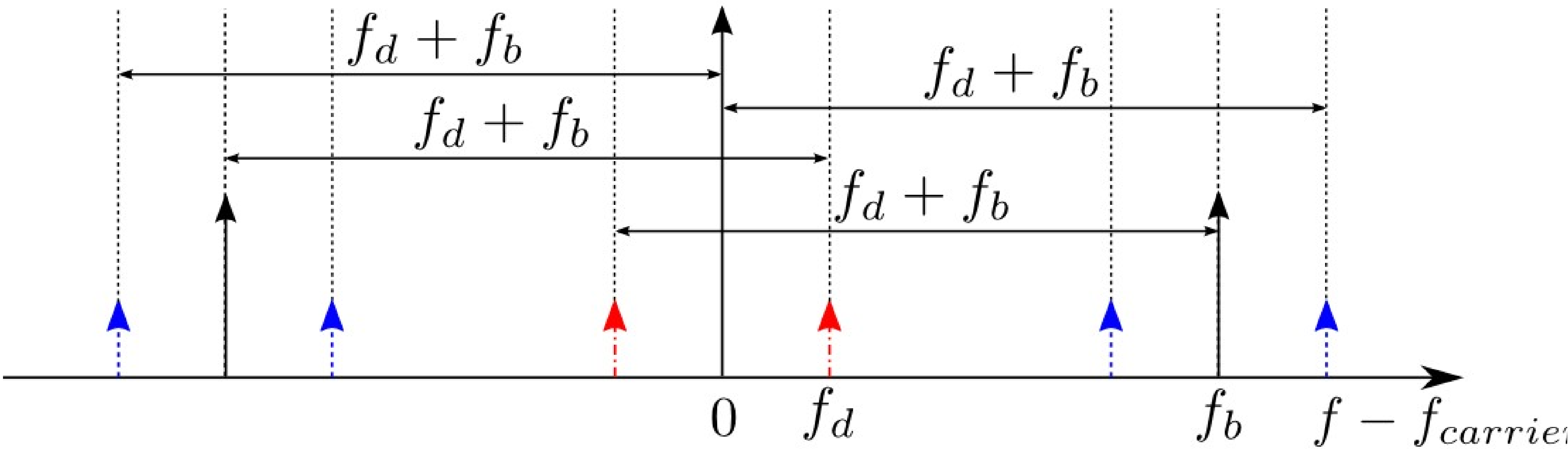
“False” gravitational wave

- Excite the elastic mode of the test mass
- Create large amplitude optical fields at audio frequencies
- Has the mode shape of the arm cavities

End test mass



Three ways to maximize SNR



- Cancel carrier alignment contribution
- Real-time SNR dither
- Constant carrier transmission

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Optimal alignment sensing of a readout mode cleaner cavity

N. Smith-Lefebvre,[1,*] S. Ballmer,[2] M. Evans,[1] S. Waldman,[1] K. Kawabe,[3] V. Frolov,[4] and N. Mavalvala[1]

[1]*LIGO Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*

[2]*Syracuse University, Syracuse, New York 12344, USA*

[3]*LIGO Hanford Observatory, P.O. Box 159, Richland, Washington 99352-0159, USA*

[4]*LIGO Livingston Observatory, P.O. Box 940, Livingston, Louisiana 70754-0940, USA*

**Corresponding author: nicolas@ligo.mit.edu*

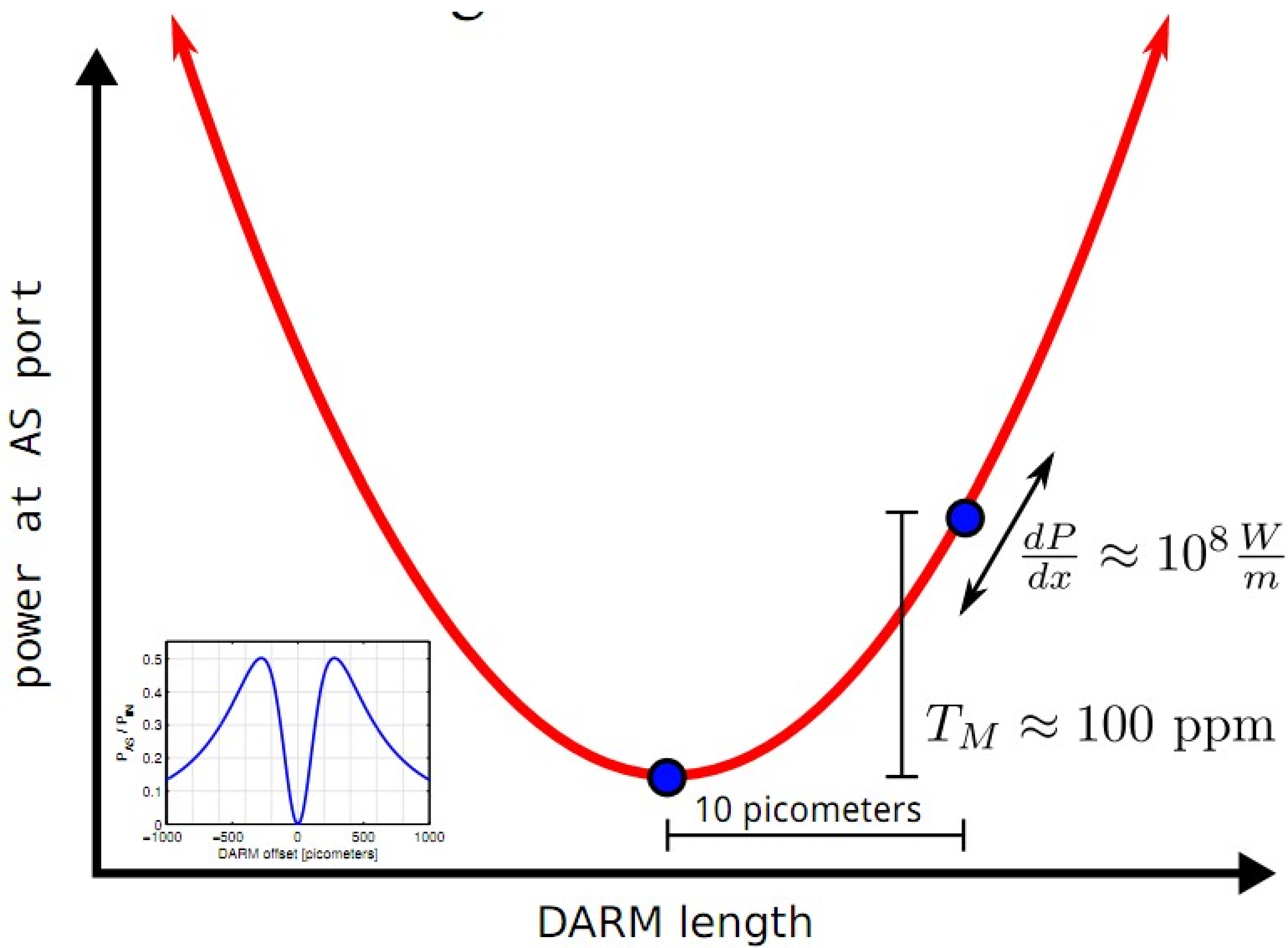
- Deployed on LIGO during S6
- I traveled to GEO to install beacon alignment with Mirko Prijatelj
- Likely to benefit future GW interferometers

DC Readout

- Alternative to standard Pound Drever Hall type demodulated readout
- Baseline for Advanced LIGO

  Benefits include:
- In principle lower shot noise
- Decreased noise coupling of laser noise and RF oscillator noise
- Simplifies readout electronics
- Greatly simplifies ability to do squeezed light injection

Description of DC Readout

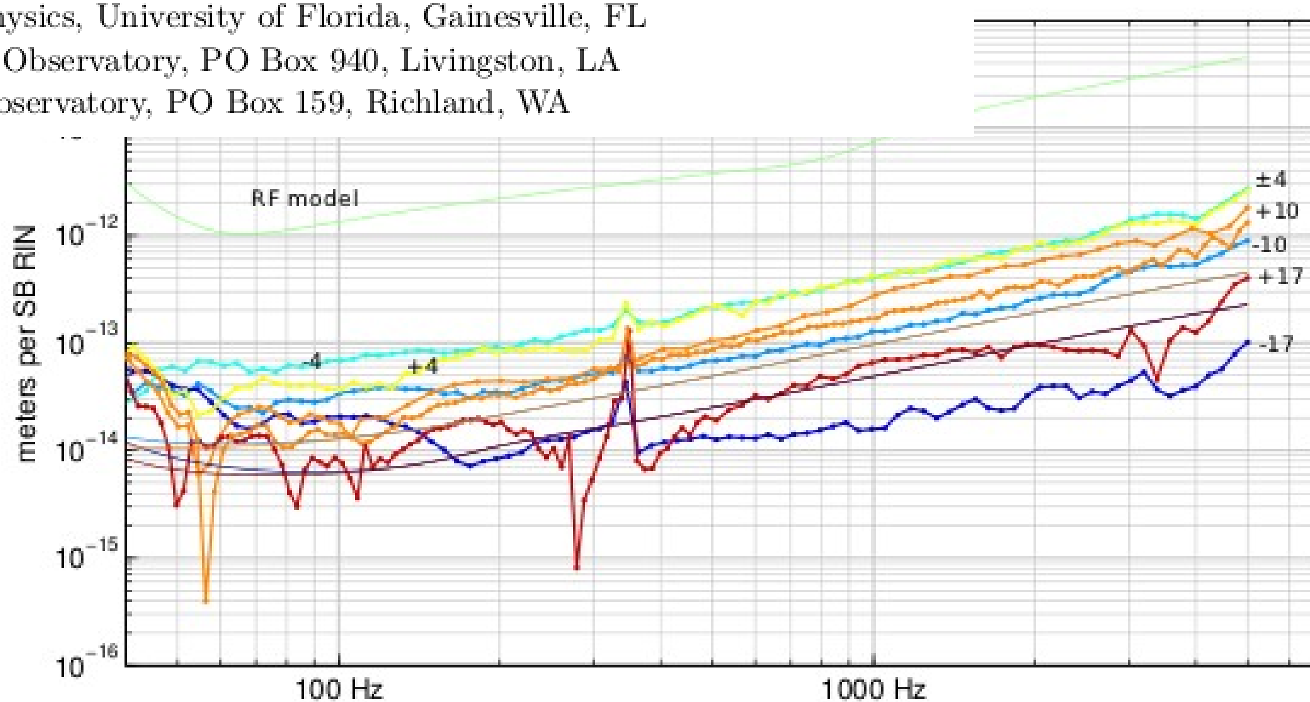


DC Readout Results

DC readout experiment in Enhanced LIGO

Tobin Fricke,[1,*] Nicolás Smith-Lefebvre,[2] Richard Abbott,[3] Rana Adhikari,[3] Katherine L Dooley,[4] Matthew Evans,[2] Peter Fritschel,[2] Valery Frolov,[5] Keita Kawabe,[6] Jeffrey S. Kissel,[2] and Sam Waldman[2]

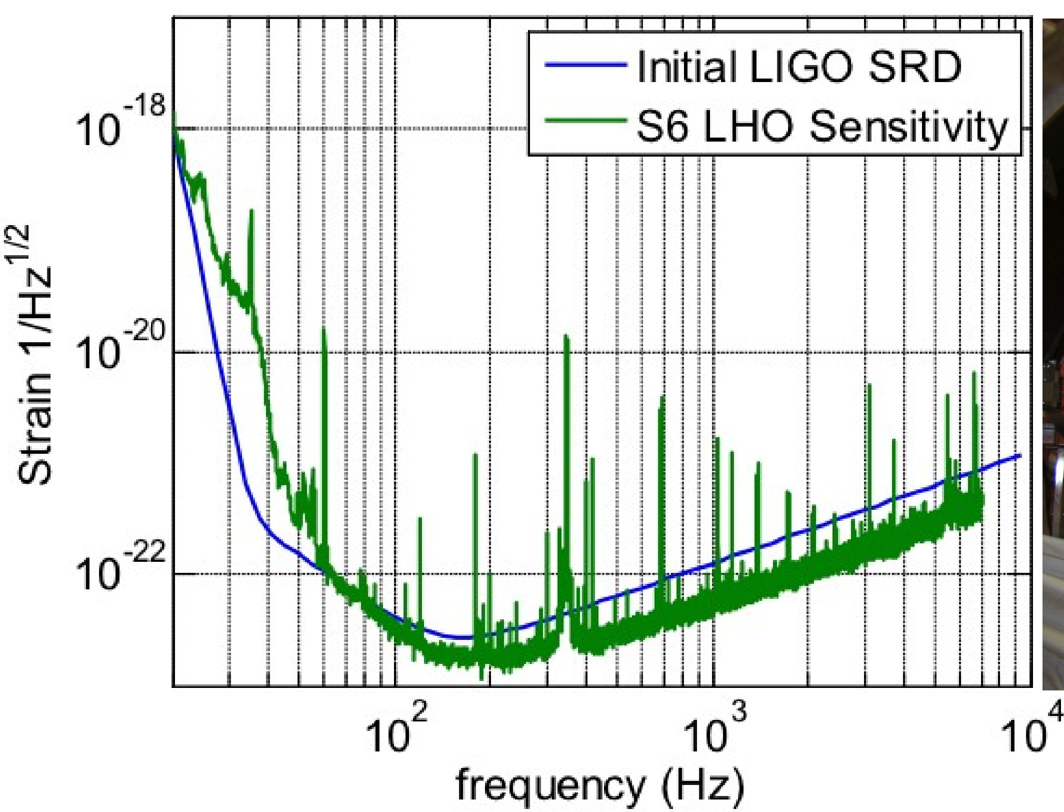
[1] Department of Physics and Astronomy, Louisiana State Univ., Baton Rouge, LA
[2] LIGO Laboratory, Massachusetts Institute of Technology, Cambridge, MA
[3] LIGO Laboratory, California Institute of Technology, MS 100-36, Pasadena, CA
[4] Department of Physics, University of Florida, Gainesville, FL
[5] LIGO Livingston Observatory, PO Box 940, Livingston, LA
[6] LIGO Hanford Observatory, PO Box 159, Richland, WA



(b) Oscillator amplitude noise coupling (H1)

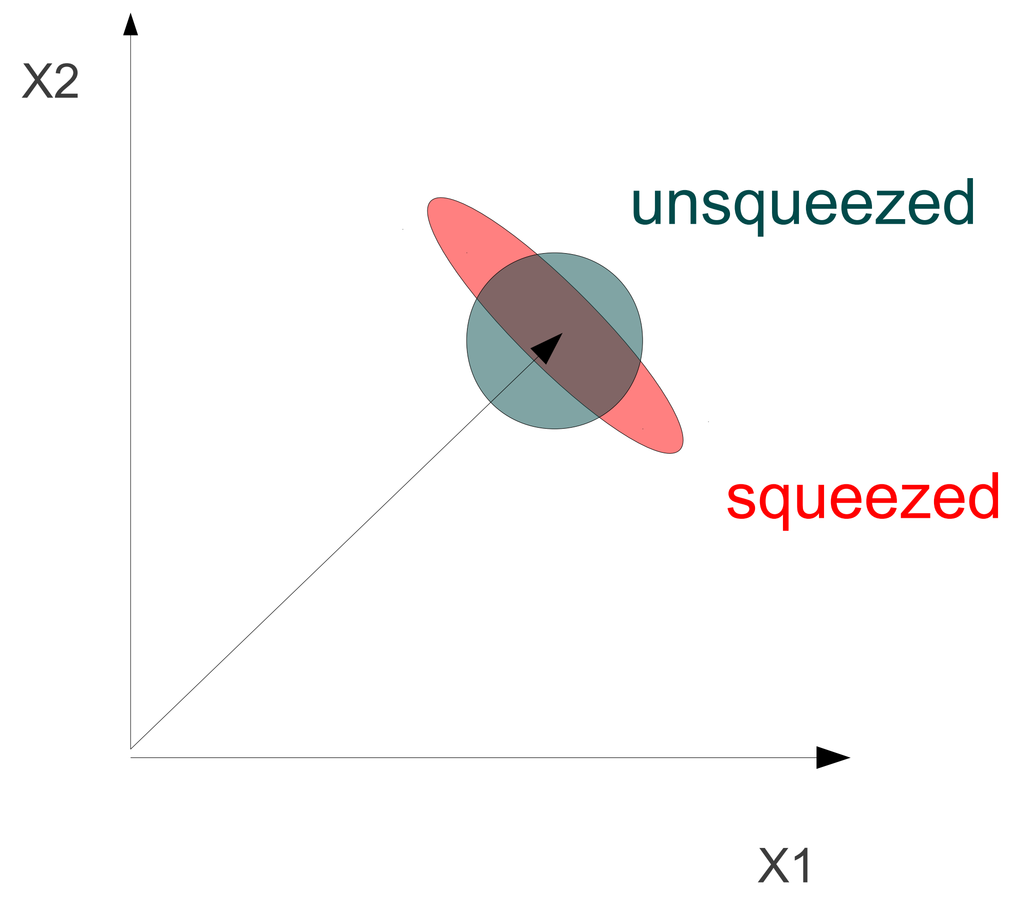
Enhanced LIGO summary

- Advanced LIGO prototypes were tested and and lessons learned
- We achieved 33% increase in astrophysical range
- Enhanced LIGO ended with 1 year of data taking, data analysis is ongoing



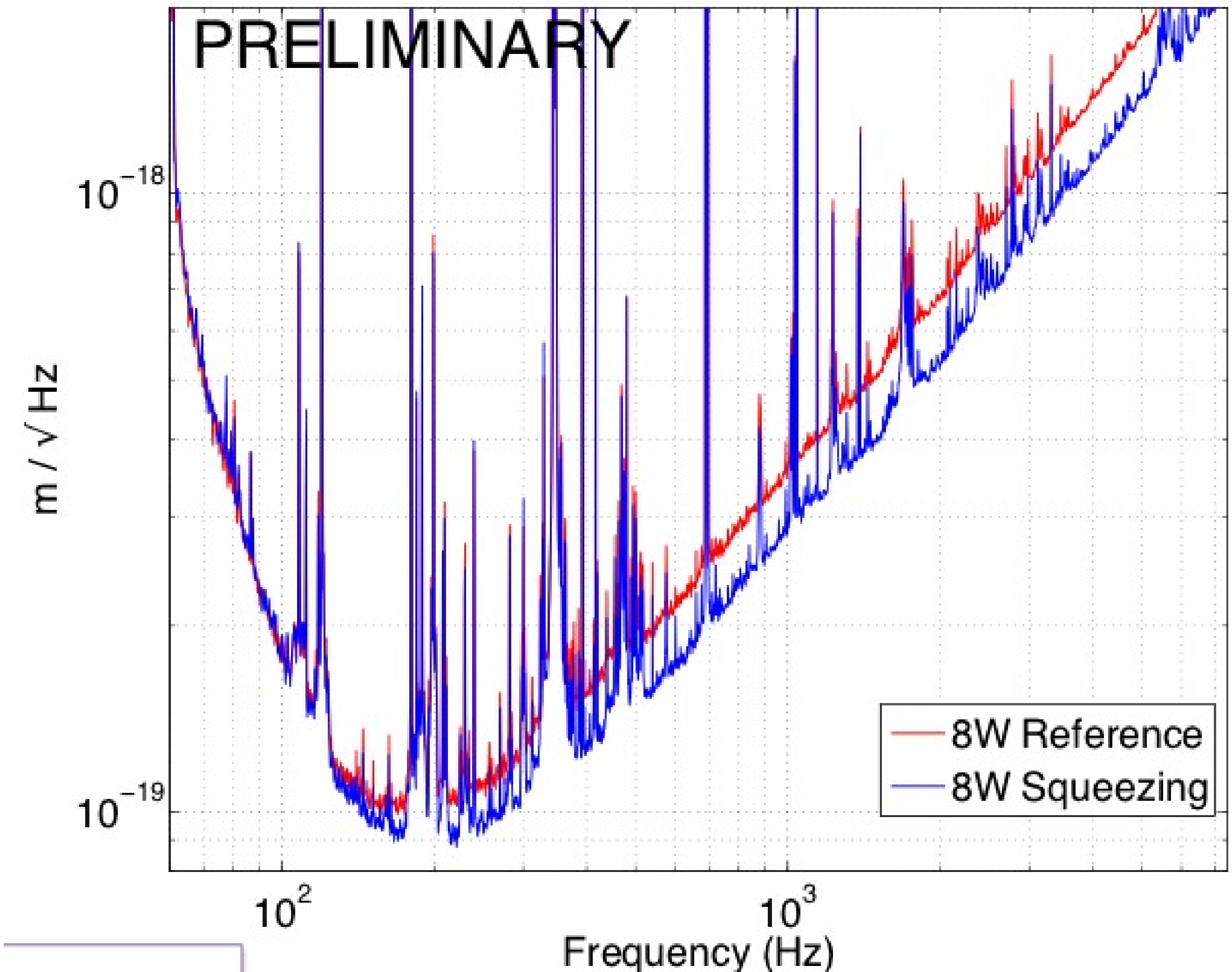
Squeezed light injection

- Manipulate quantum noise correlations of photons
- Reduces shot noise
- Same effect on noise as increased laser power, but without increased thermal load



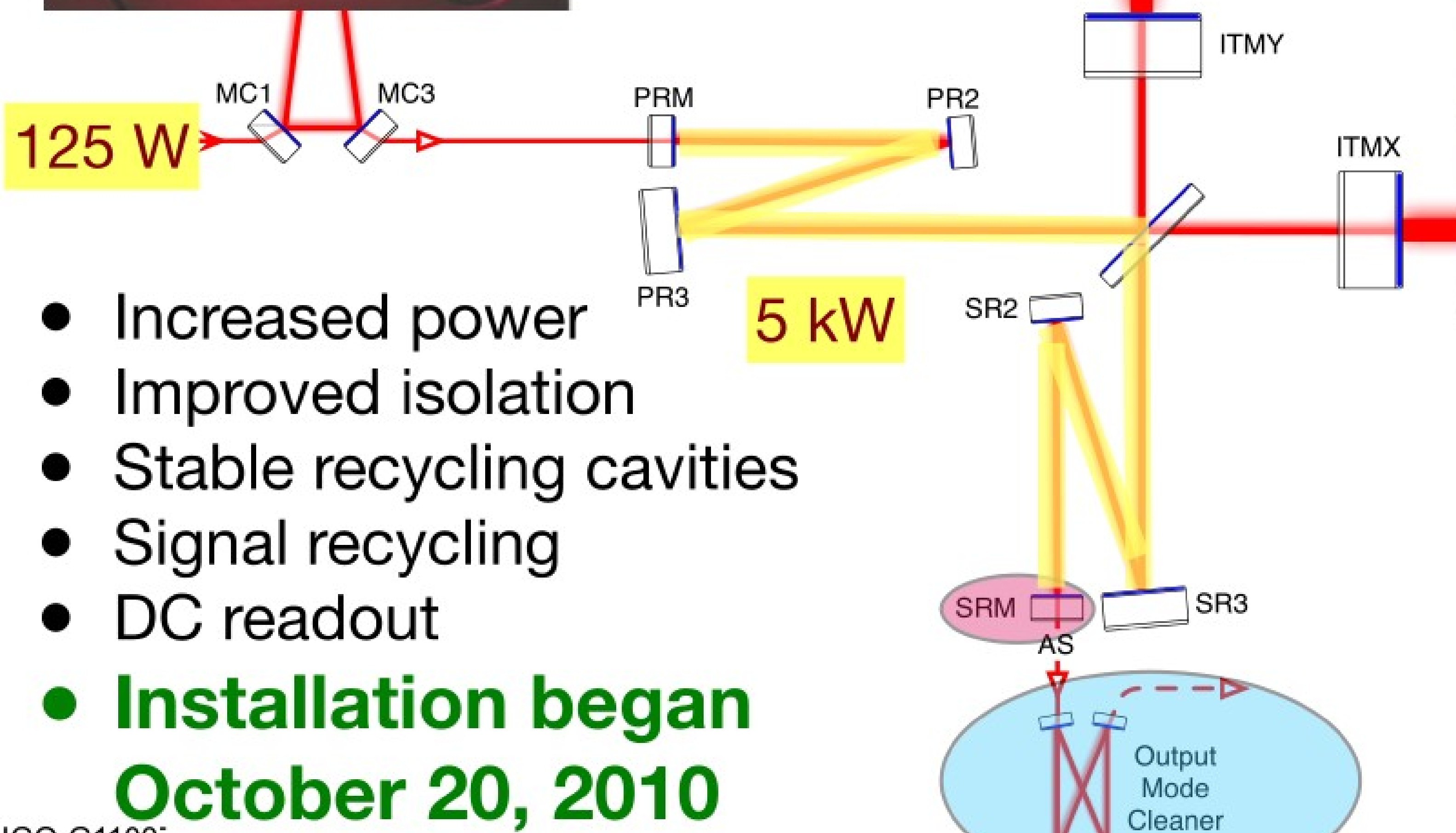
Squeezed light results

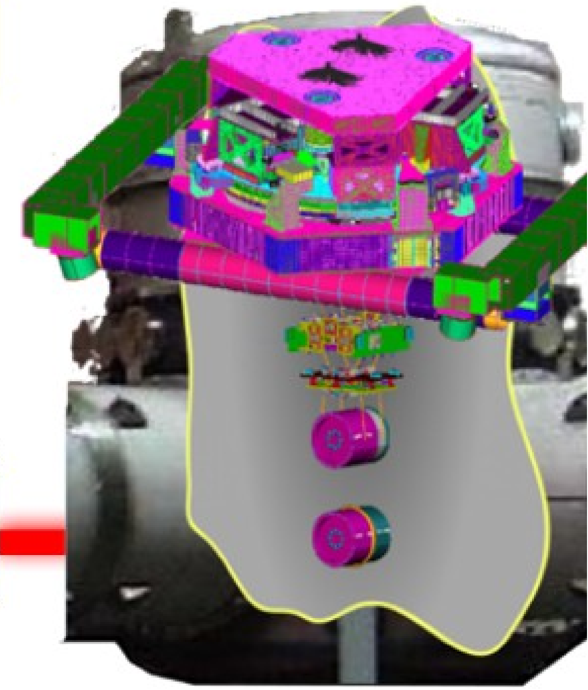
- 2dB of noise reduction down to 150Hz
- Squeezing level consistent with known losses
- No additional noise added



Publications coming...

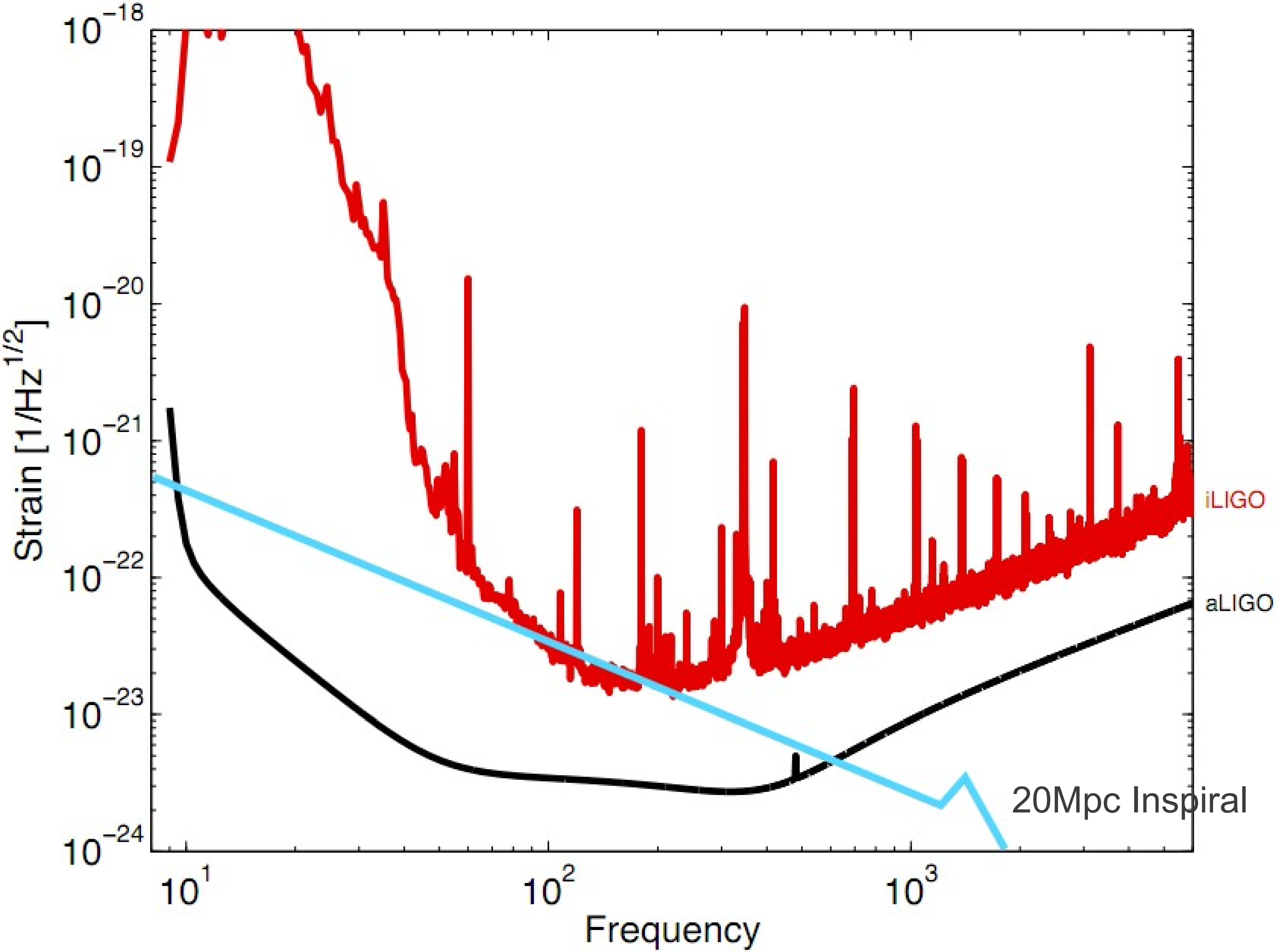
Advanced LIGO



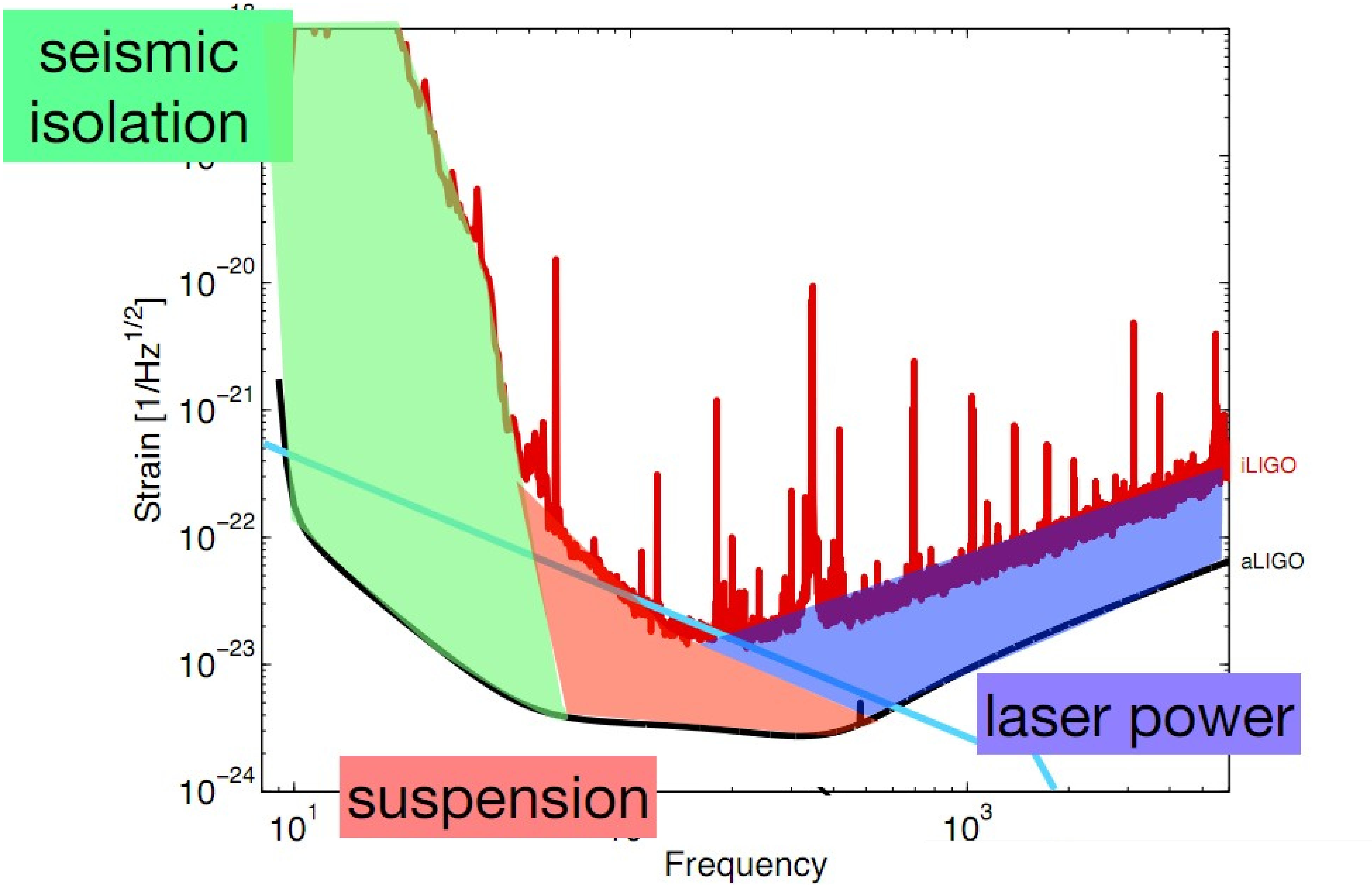


- Increased power
- Improved isolation
- Stable recycling cavities
- Signal recycling
- DC readout
- **Installation began October 20, 2010**

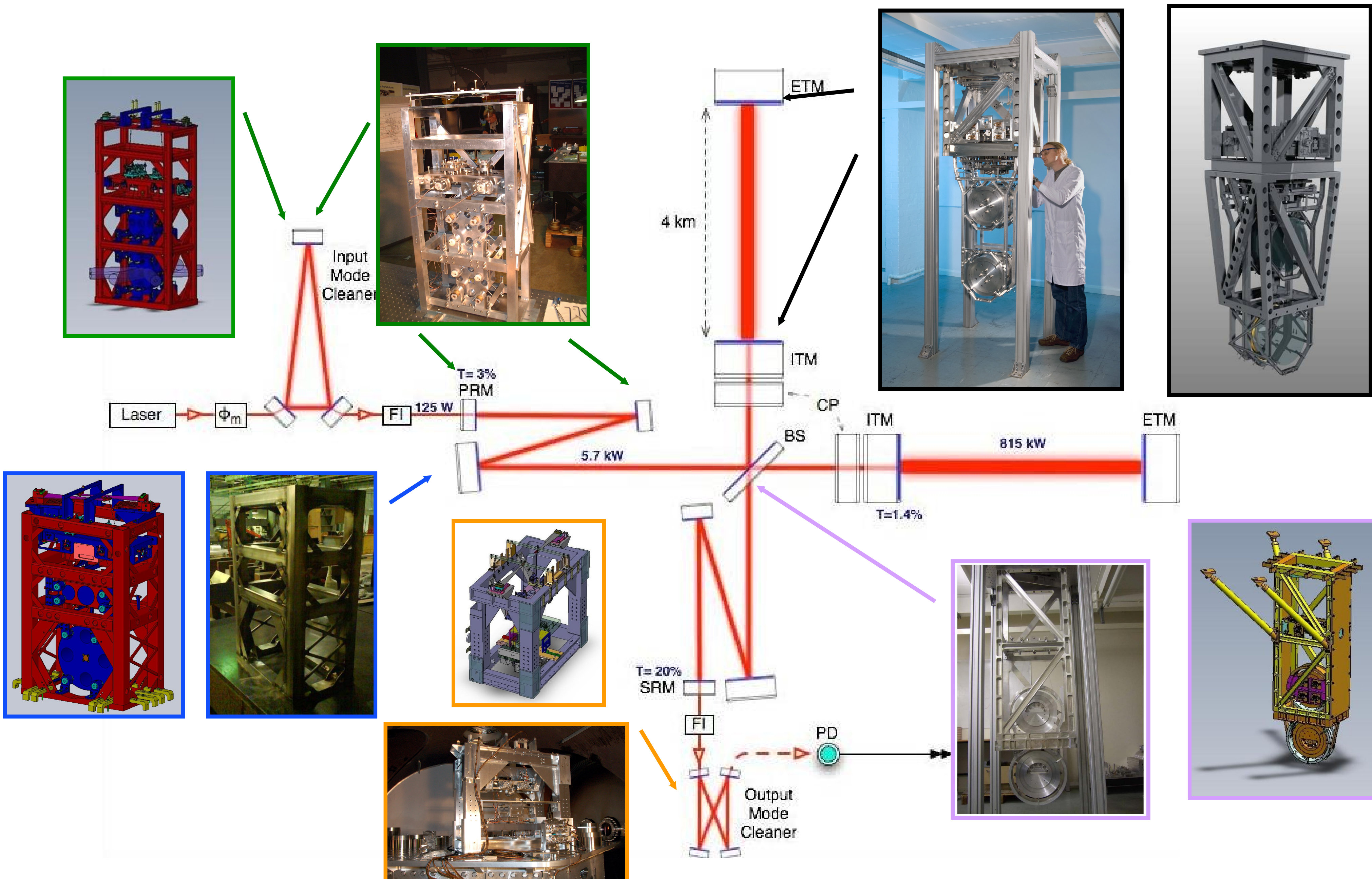
Sensitivity Increase



Sensitivity Increase



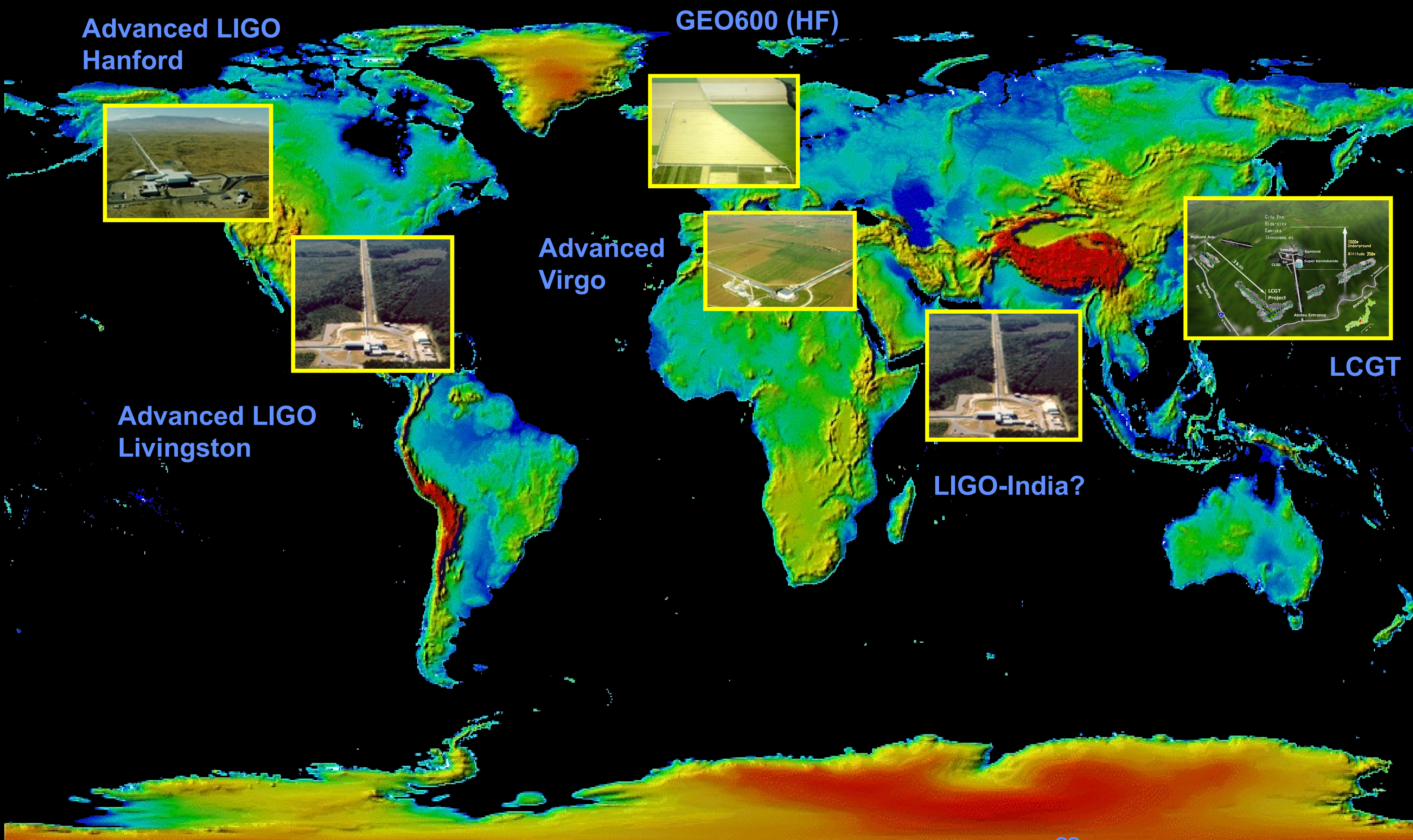
Advanced LIGO Suspensions



Recent news

- After conclusion of squeezing test, last initial LIGO detector was decommissioned (Dec 5th)
- First aLIGO suspensions and seismic platforms installed (Dec 9th)

The Advanced GW Detector Network



Thank you

どうもありがとうございます。

Gracias

Merci

Danke