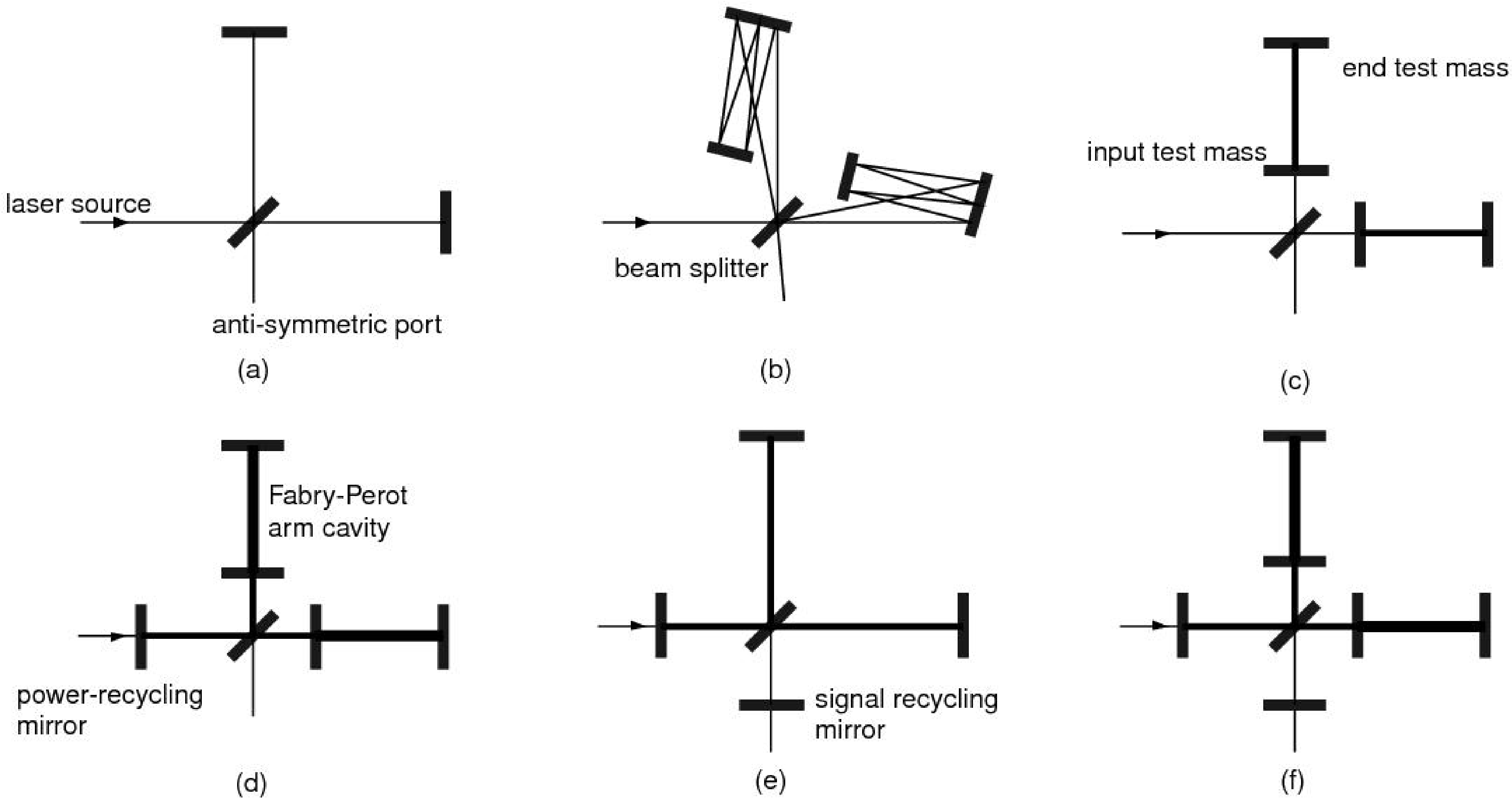
LIGO Interferometry

CLEO/QELS Joint Symposium
on Gravitational Wave Detection,
Baltimore, May 24, 2005

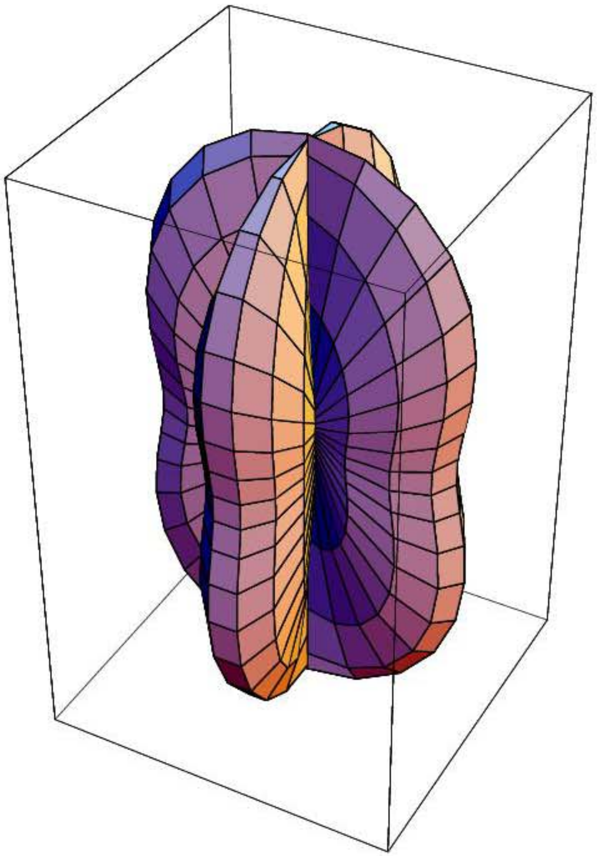
Daniel Sigg

G050253-00-D

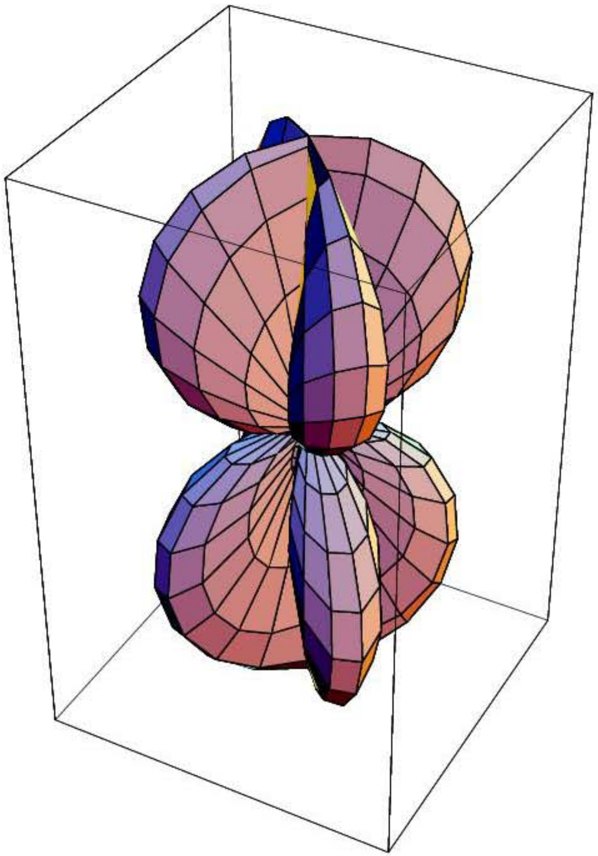
Interferometer Configurations



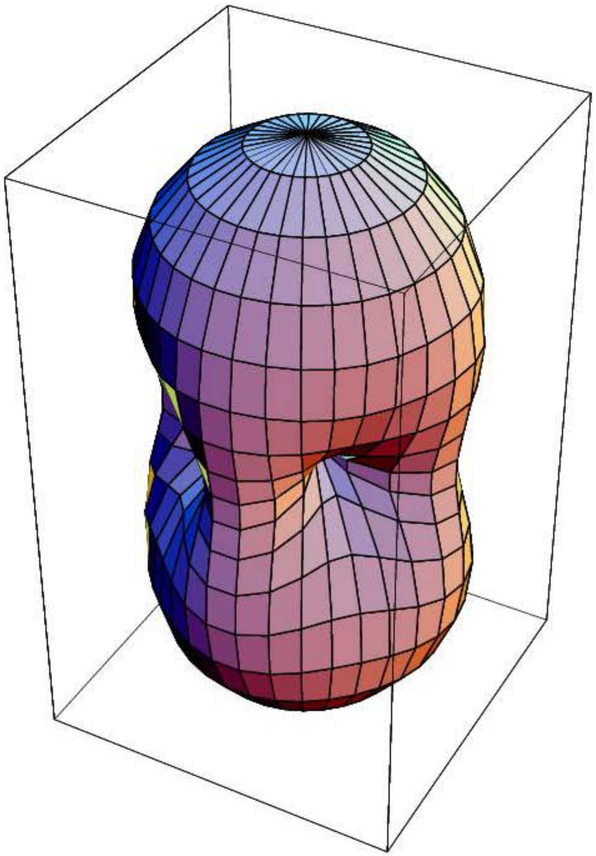
Antenna Pattern



+ polarization

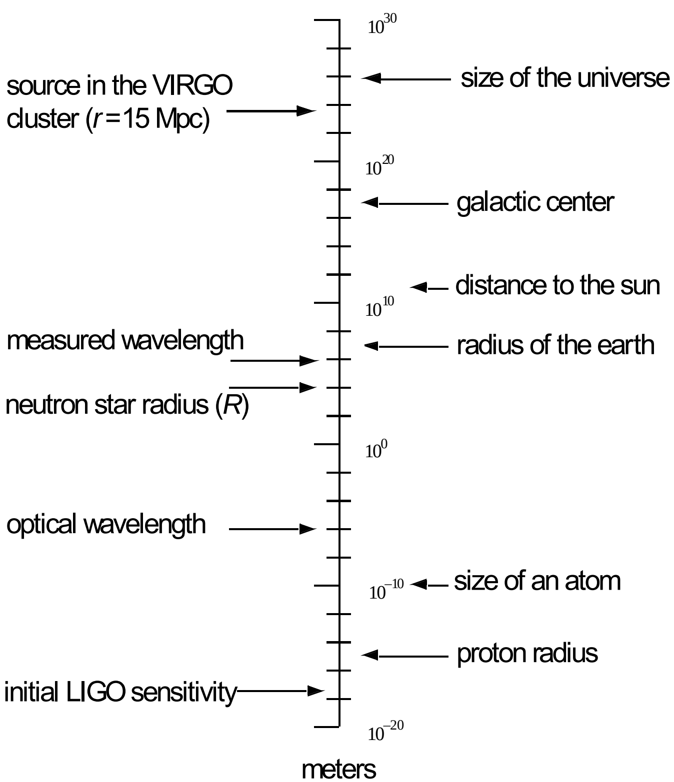


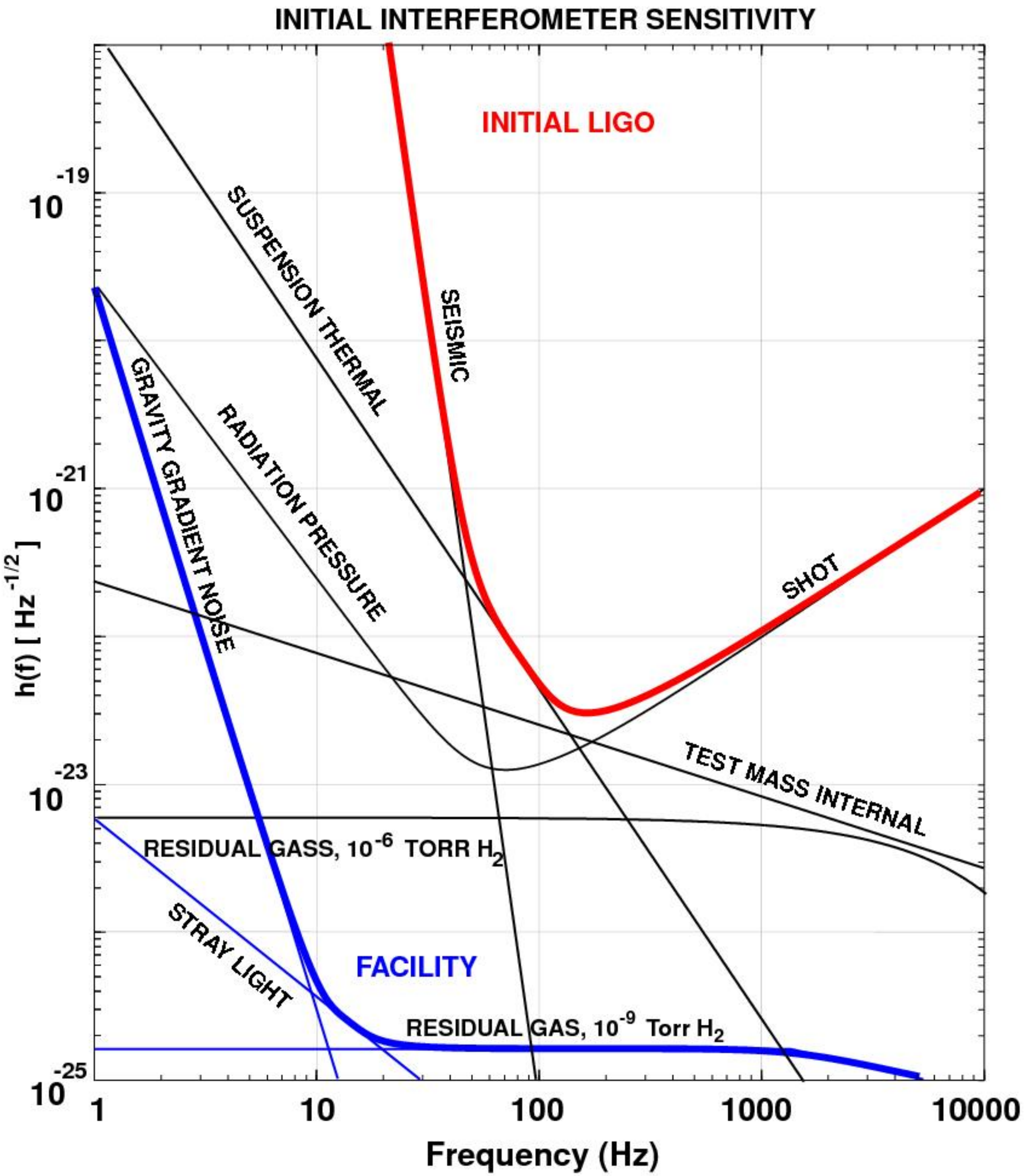
× polarization



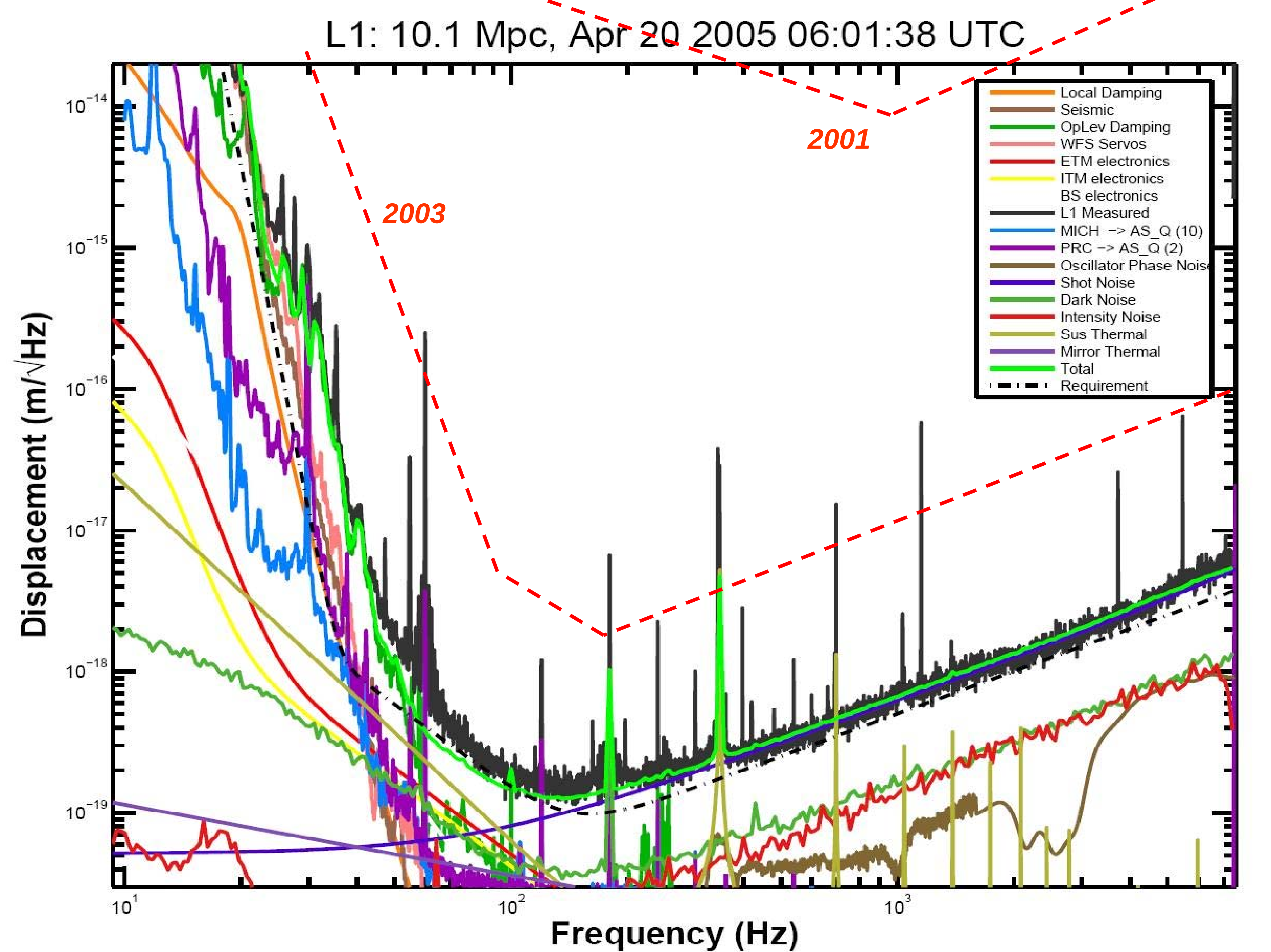
averaged

Sensitivity





G050253-00-D



L1: 10.1 Mpc, Apr 20 2005 06:01:38 UTC
Local Damping
Seismic
OpLev Damping
WFS Servos
ETM electronics
ITM electronics
BS electronics
L1 Measured
MICH -> AS_Q (10)
PRC -> AS_Q (2)
Oscillator Phase Noise
Shot Noise
Dark Noise
Intensity Noise
Sus Thermal
Mirror Thermal
Total
Requirement
2001
2003
Displacement (m/√Hz)
Frequency (Hz)

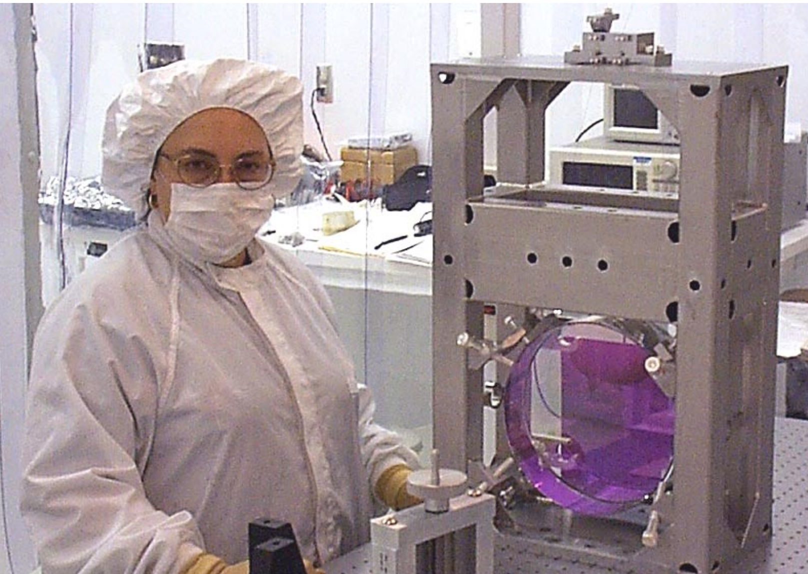
Seismic Isolation

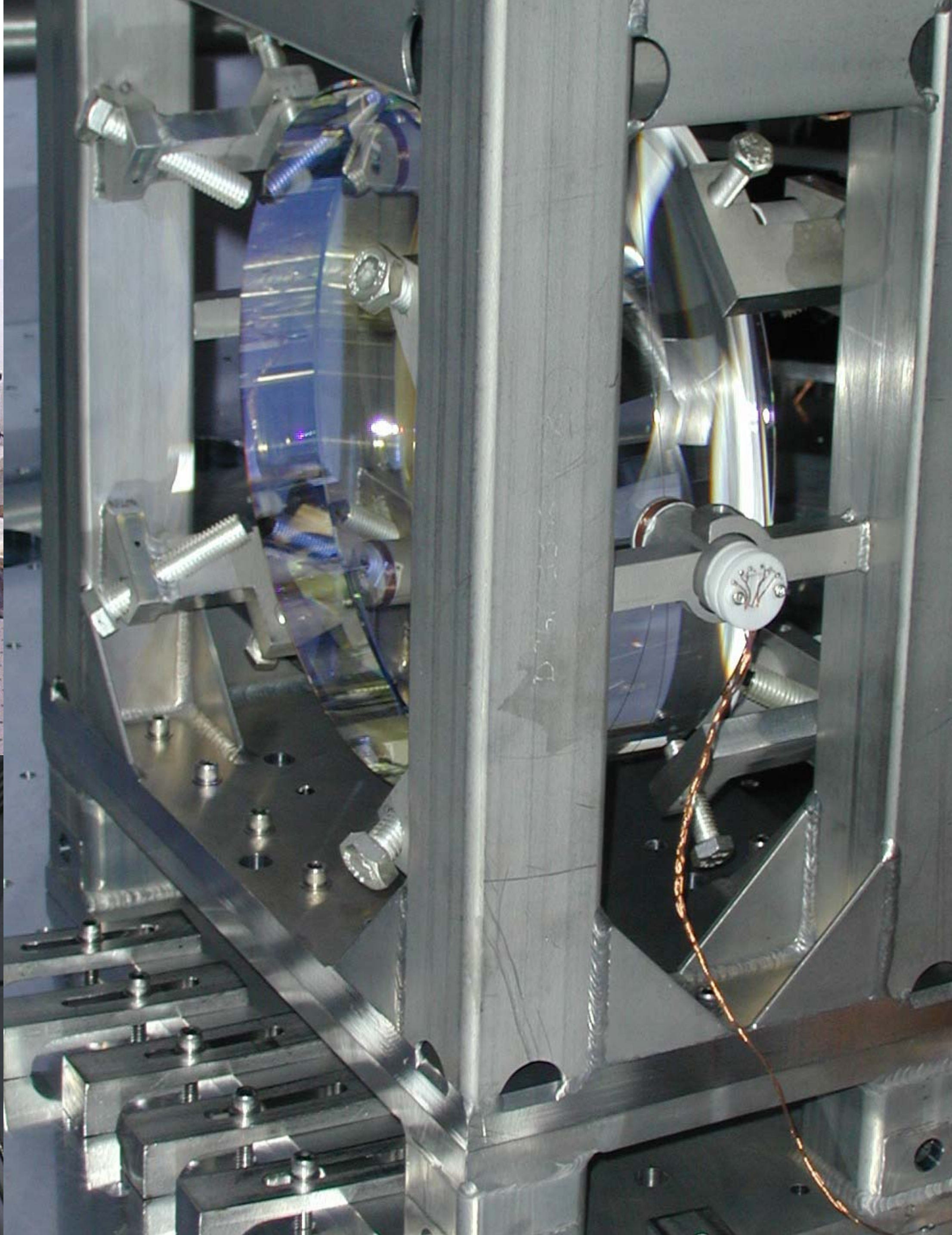


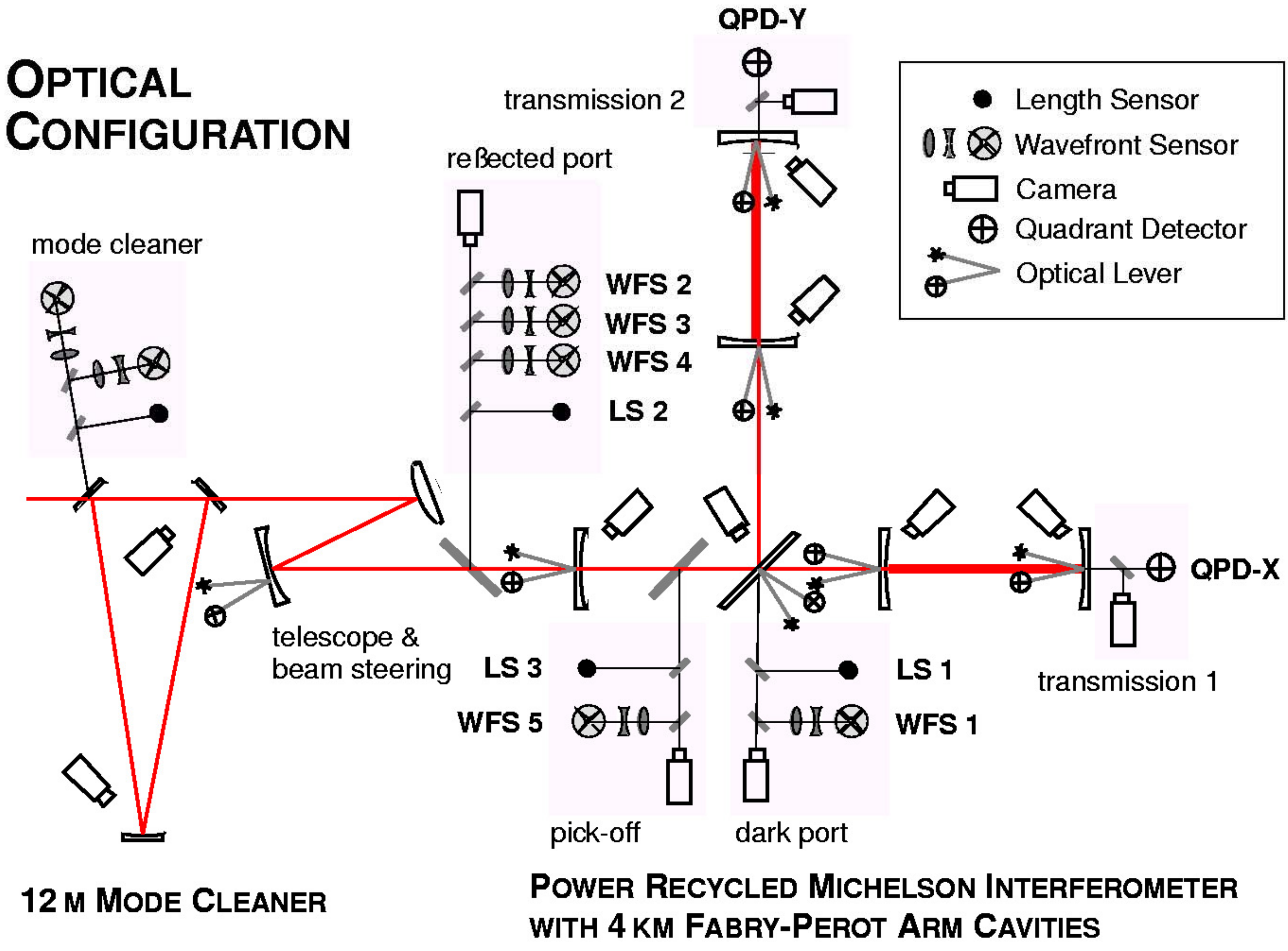


LIGO I

LIGO Suspensions





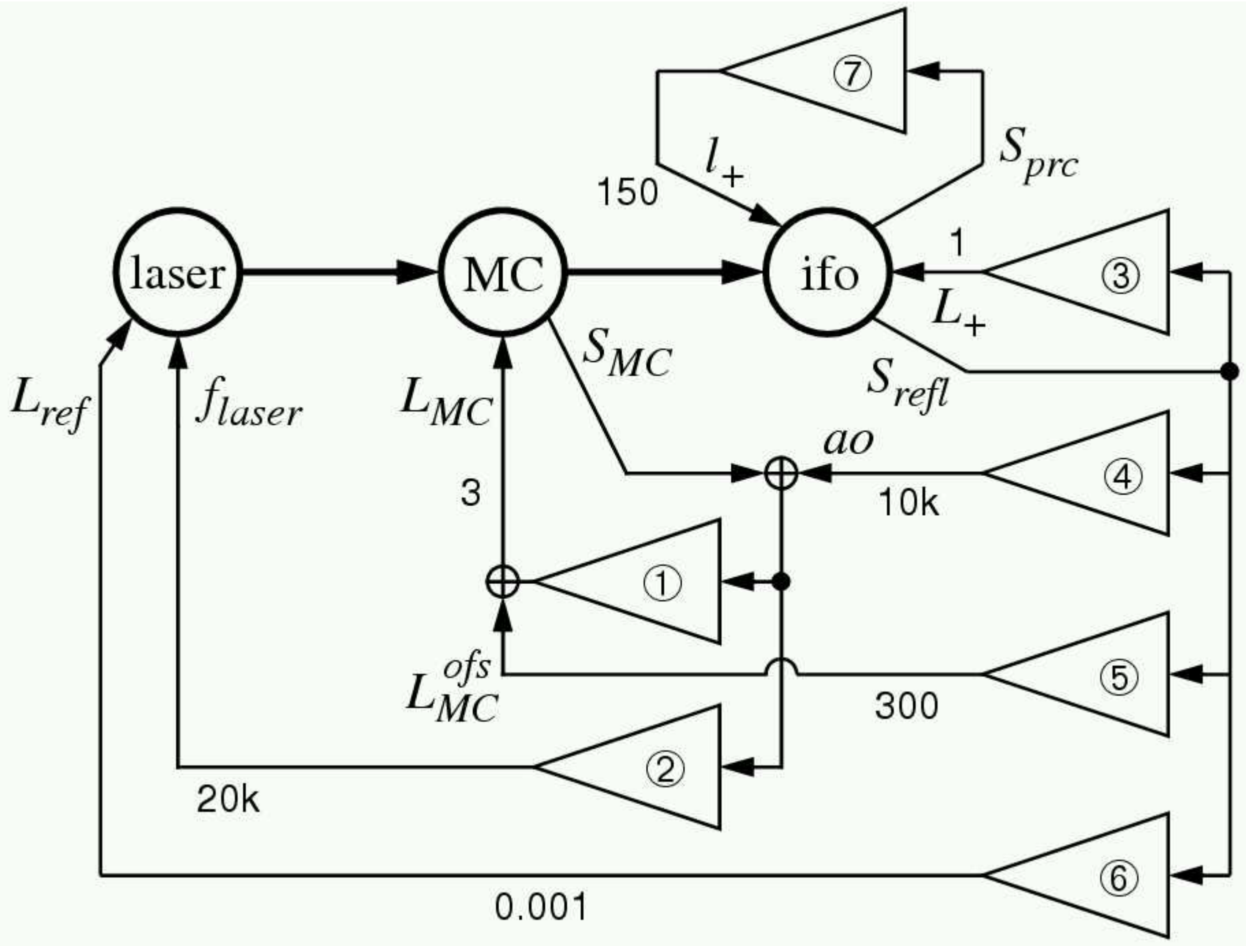


OPTICAL CONFIGURATION
QPD-Y
transmission 2
re ßected port
mode cleaner
WFS 2
WFS 3
WFS 4
LS 2
Length Sensor
Wavefront Sensor
Camera
Quadrant Detector
Optical Lever
QPD-X
telescope &
beam steering
LS 3
WFS 5
LS 1
WFS 1
transmission 1
pick-off
dark port
12 M MODE CLEANER
POWER RECYCLED MICHELSON INTERFEROMETER
WITH 4 KM FABRY-PEROT ARM CAVITIES

Some Requirements

- Sensitivity: ~10^{-19} m/√Hz at 150 Hz
- Controller range: ~100 µm (tides)
- Control of diff. arm length: ≤10^{-13} m rms
- Laser intensity noise: ≤10^{-7} /√Hz at 150 Hz
- Frequency noise: ≤3×10^{-7} Hz/√Hz at 150 Hz
- Angular Control: ≤10^{-8} rad rms
- Input beam jitter: ≤4×10^{-9} rad/√Hz at 150 Hz

Length Sensing and Control



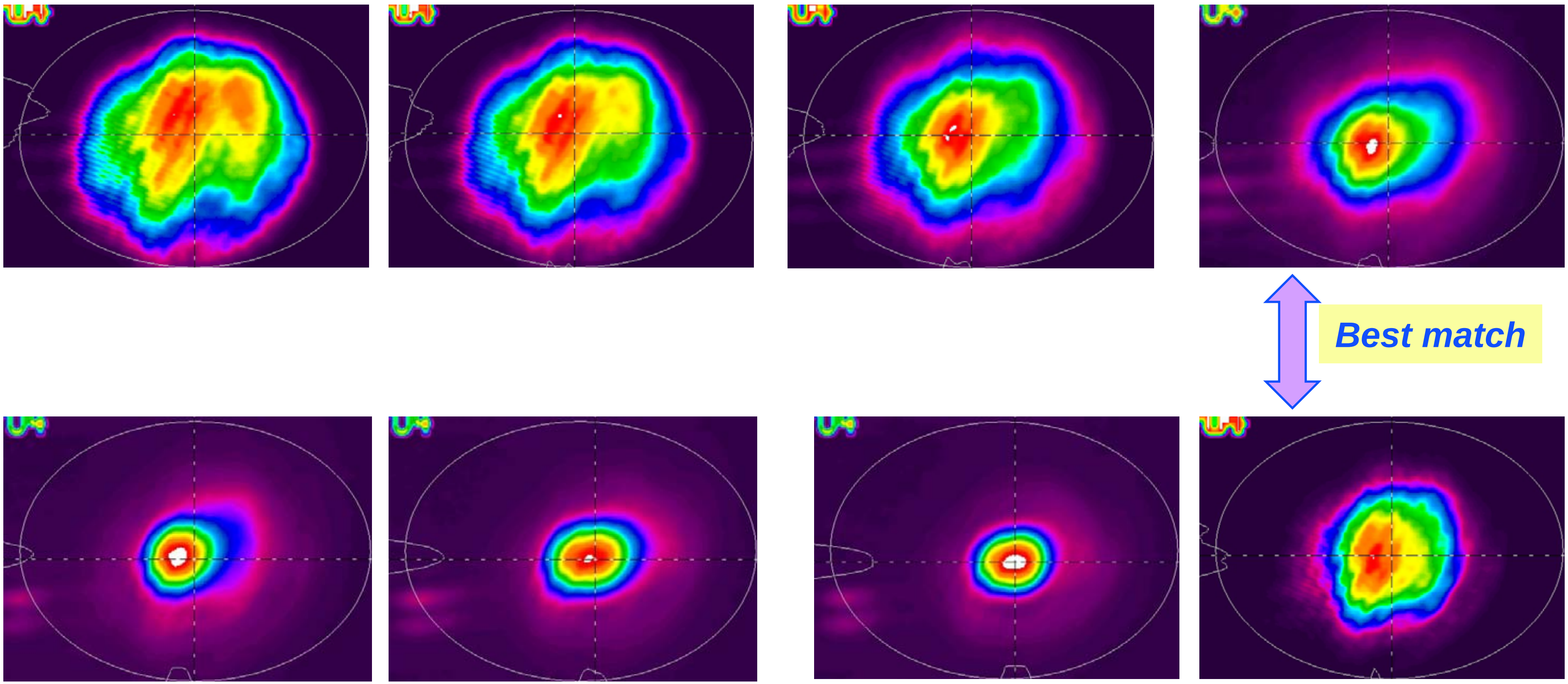
- Separate common and differential mode
  - Diff. arm
  - Michelson
  - Common arm
  - PR cavity
- Sensors
  - Anti-symmetric port
  - In reflection
  - PR cavity sample

The Auto-Alignment System

- Optical levers for damping suspension & stack modes
- Wavefront RF sensors for 10 angular dofs
- Quadrant detectors for beam positions on ends
- Video analysis of beam splitter image for input beam position

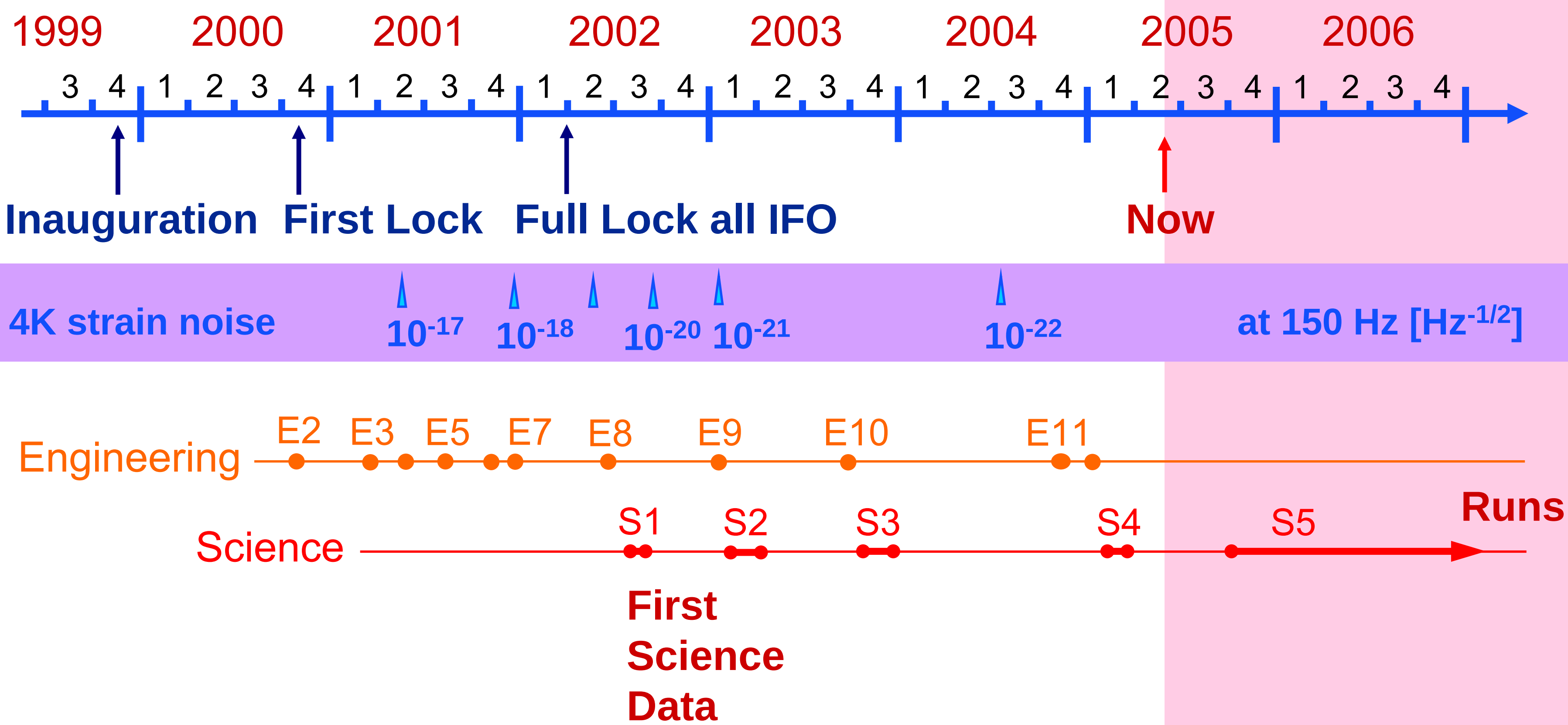
Sideband Images as Function of Thermal Heating

No Heating | 30 mW | 60 mW | 90 mW



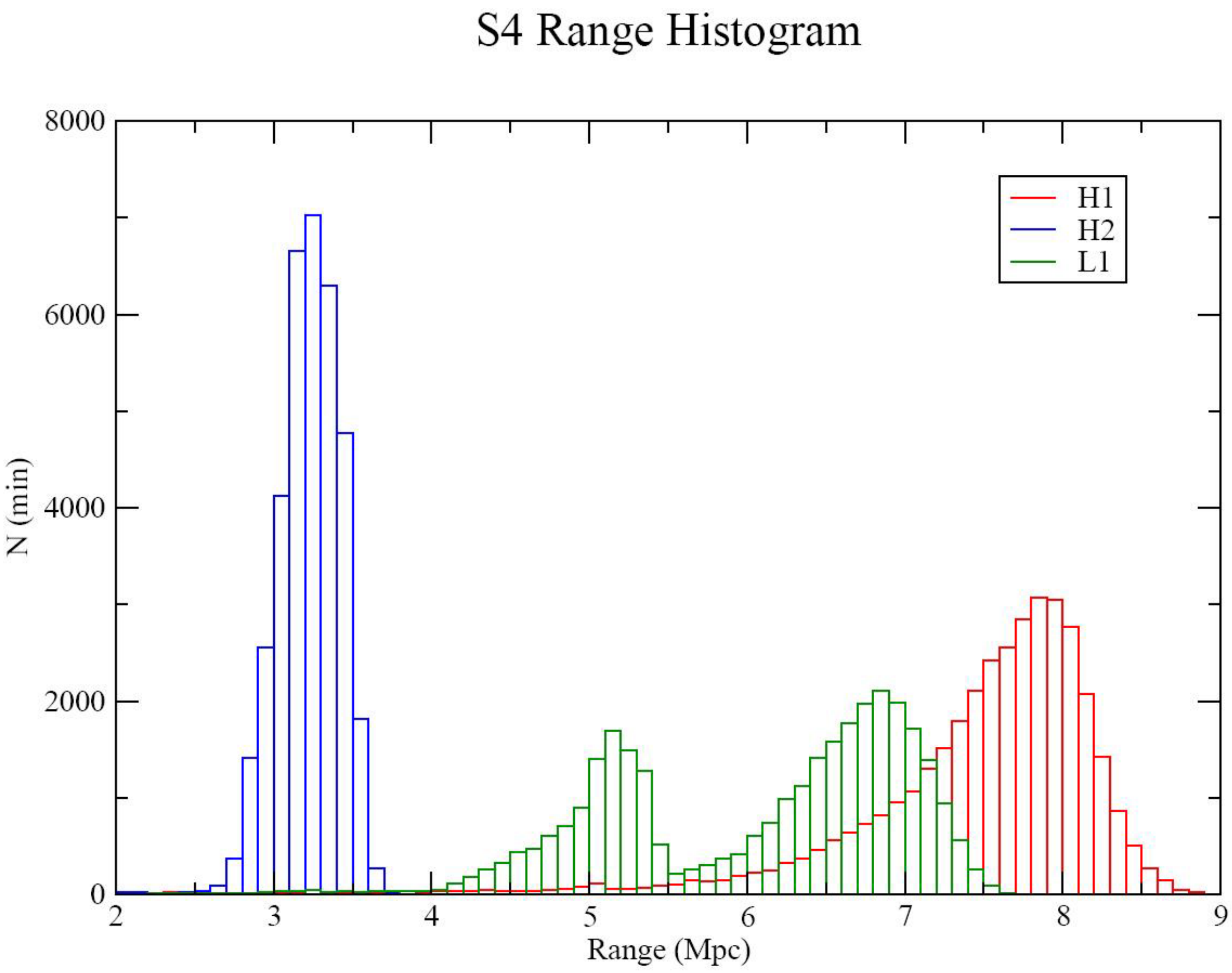
120 mW | 150 mW | 180 mW | Input beam

Time Line


1999
2000
2001
2002
2003
2004
2005
2006
3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Inauguration
First Lock
Full Lock all IFO
Now
4K strain noise
10^{-17}
10^{-18}
10^{-20}
10^{-21}
10^{-22}
at 150 Hz [$Hz^{-1/2}$]
Engineering
E2 E3 E5 E7 E8 E9 E10 E11
Runs
Science
S1 S2 S3 S4 S5
First Science Data

The 4th Science Run

- Dates (2005):
  - Start: 22 Feb
  - Stop: 23 Mar
- Duty cycle:
  - H1: 80%
  - L1: 74%
  - H2: 81%
  - Triple coincidence: 57%



Results from the 1st/2nd Science Run

- Binary inspirals (S2):
  - Neutron star binary coalescence: range up to 1.5 Mpc, rate ≤ 47/y/MW (90% CL)
  - Black hole coalescence (0.2-1$M_\odot$) in Galactic halo: rate ≤ 63/y/MW (90% CL)
- Pulsars (S2):
  - Limits on 28 pulsars
  - Upper limits on h as low as 2×10^{-24} (95% CL) and as low as 5×10^{-6} on the eccentricity
- Stochastic background (S1):
  - Energy limit as fraction of closure density: $h^2_{100}\Omega_0 \leq 23 \pm 4.6$ (90% CL)
  - **PRELIMINARY** S2: $h^2_{100}\Omega_0 \leq 0.018 +0.007-0.003$ (90% CL)
- Burst (S2):
  - Sensitivity: $h_{rss} \sim 10^{-20} - 10^{-19}$ /√Hz, rate ≤ 0.26/day (90% CL)
  - GRB030329: $h_{rss} \leq 6\times10^{-21}$ /√Hz

Summary

- Sophisticated feedback compensation networks are essential in running a modern gravitational-wave interferometer
- All LIGO interferometers are within a factor of 2 of design sensitivity over a broad range of frequencies
- For sources like binary neutron star coalescence we can see beyond our own galaxy!
- Join Einstein@home (einstein.phys.uwm.edu)