IEEE 1996 - Nuclear Science Symposium

Anaheim, CA

November 5, 1996

Caltech/MIT/NSF

Laser Interferometer Gravitational Wave Observatory

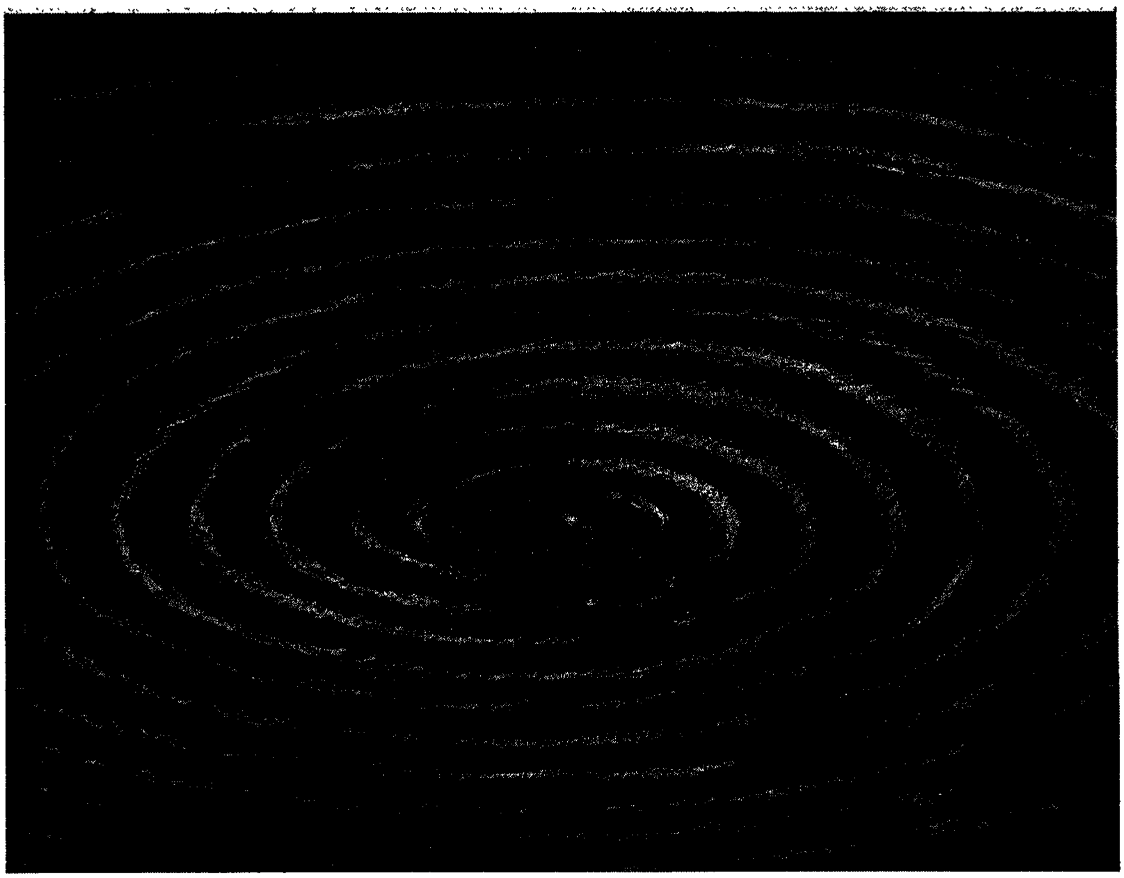
Searching for Gravitational Waves With LIGO

Gary Sanders

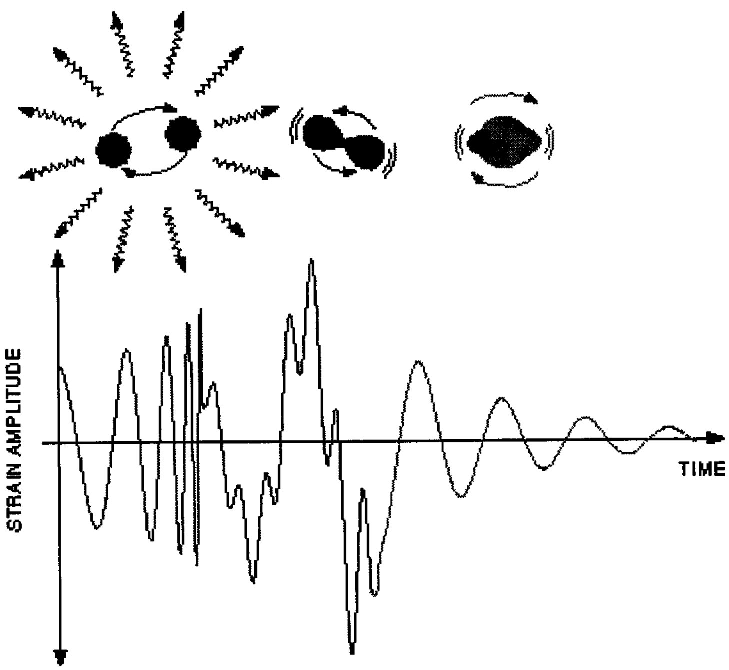
California Institute of Technology

+ photos not included GS

Gravitational Radiation

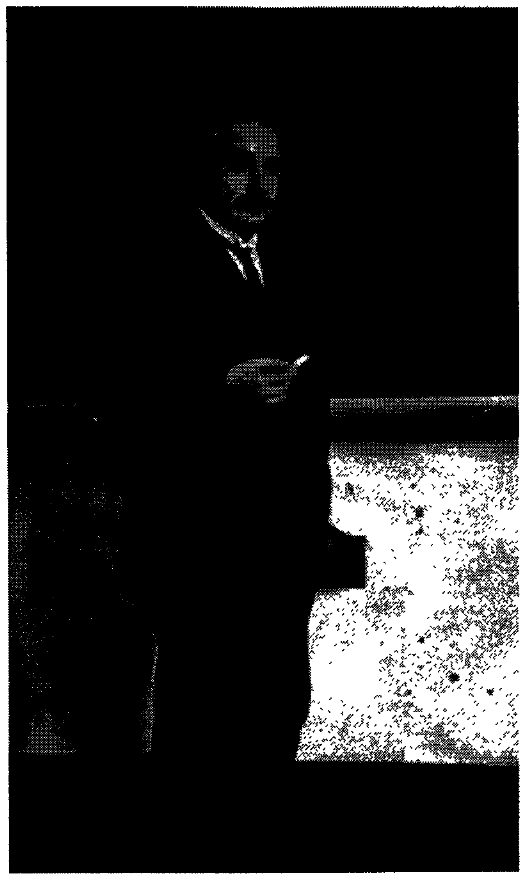


A Gravitational Wave Signal



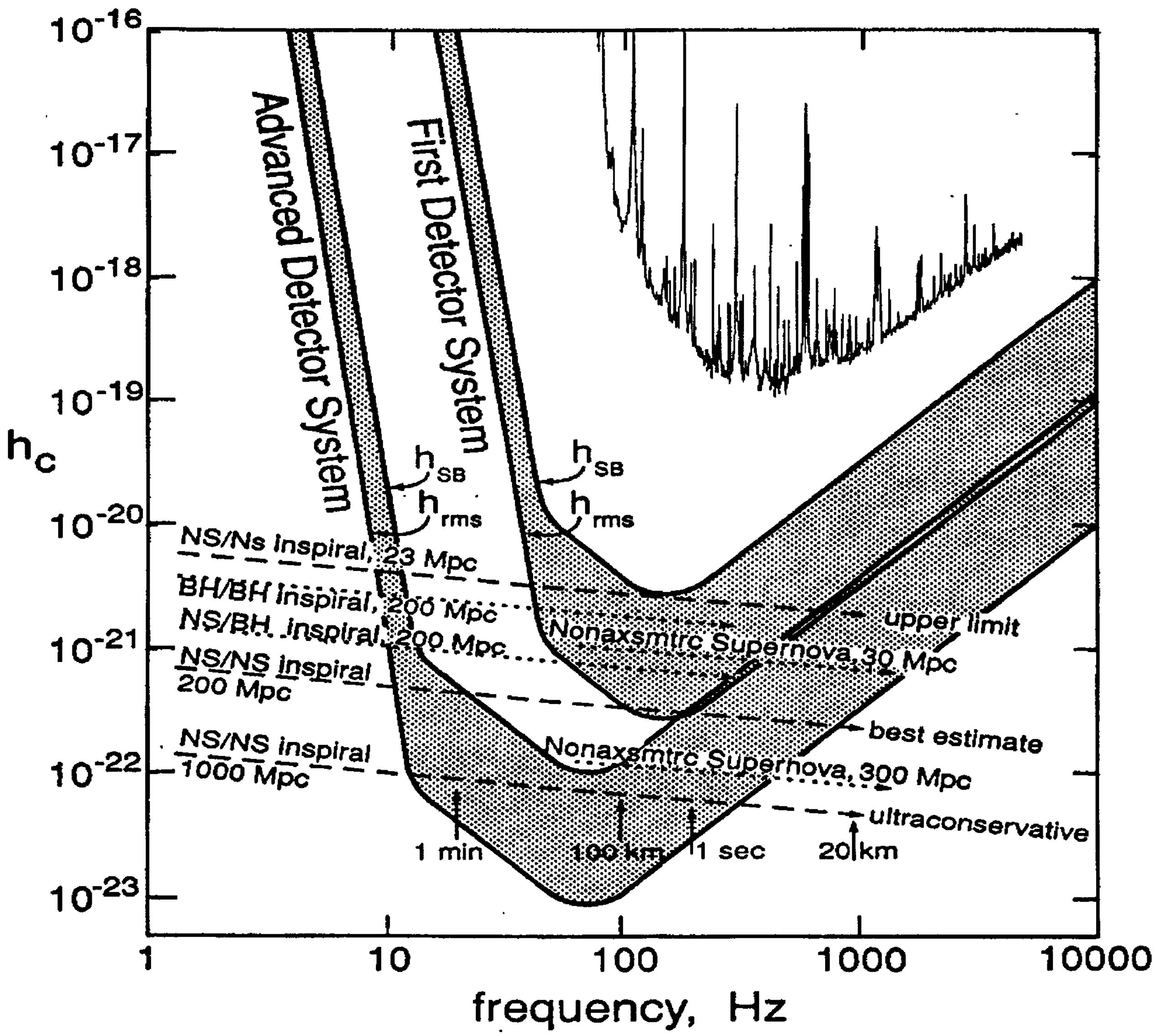
Signal from a neutron star - neutron star binary inspiral and coalescence

Einstein

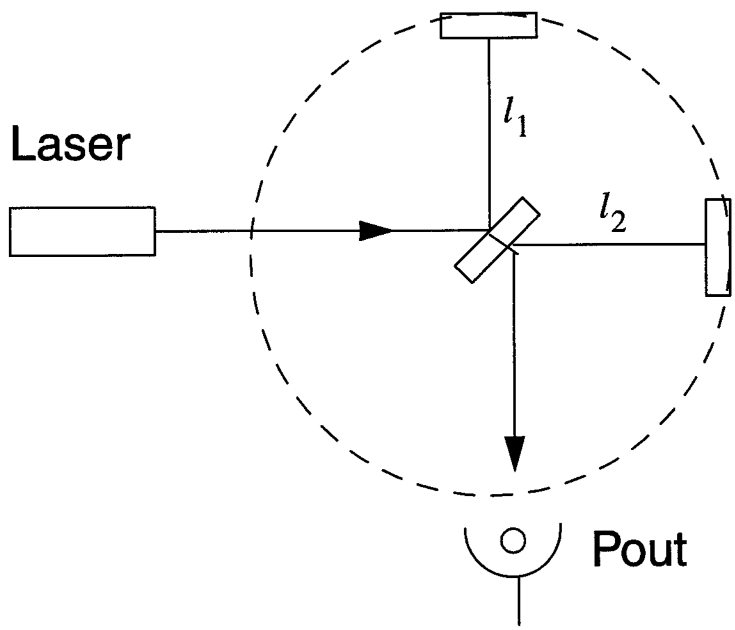


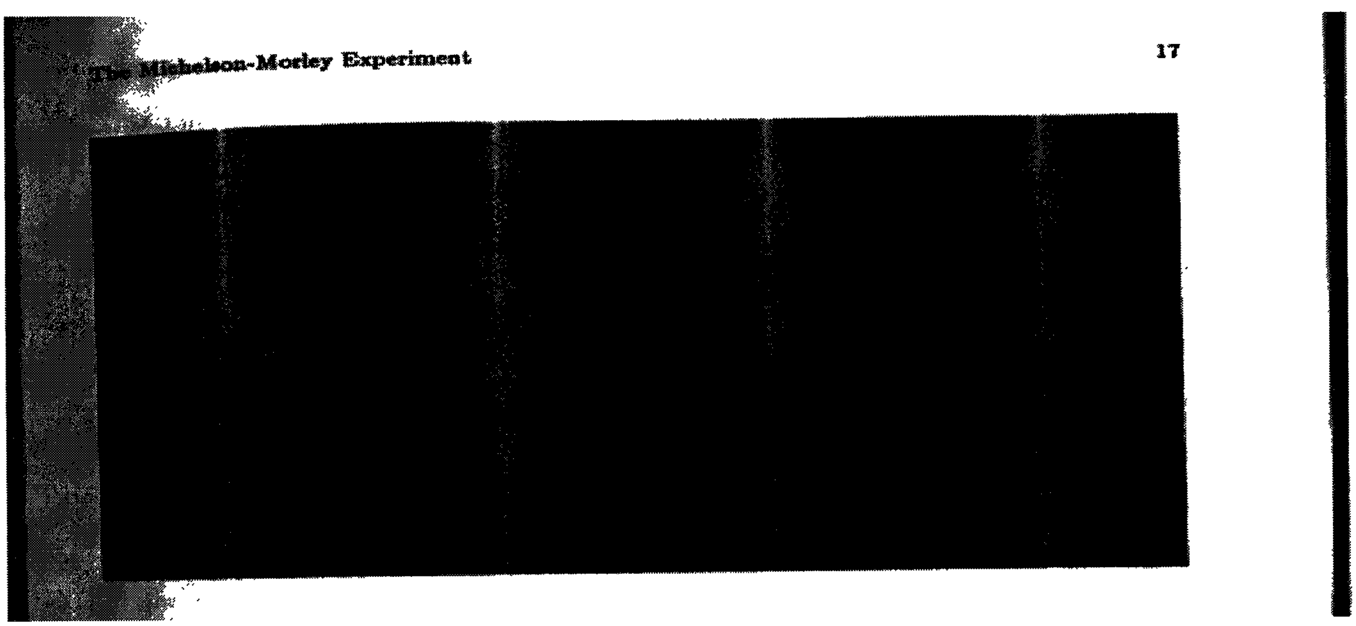
- ››gravitational radiation
- ››photons as quanta
- ››thermal physics - Brownian motion
- ››even “Big Science”

LIGO Detector Spectral Noise Density

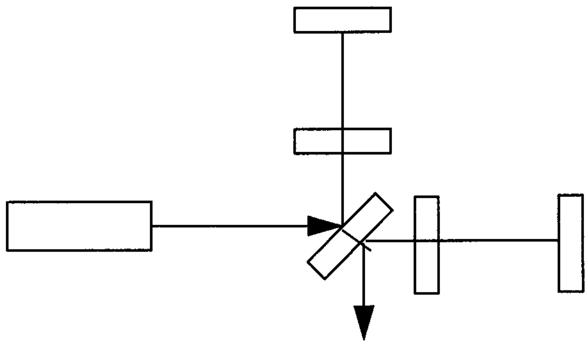


Michelson Interferometer





Fabry-Perot Interferometer



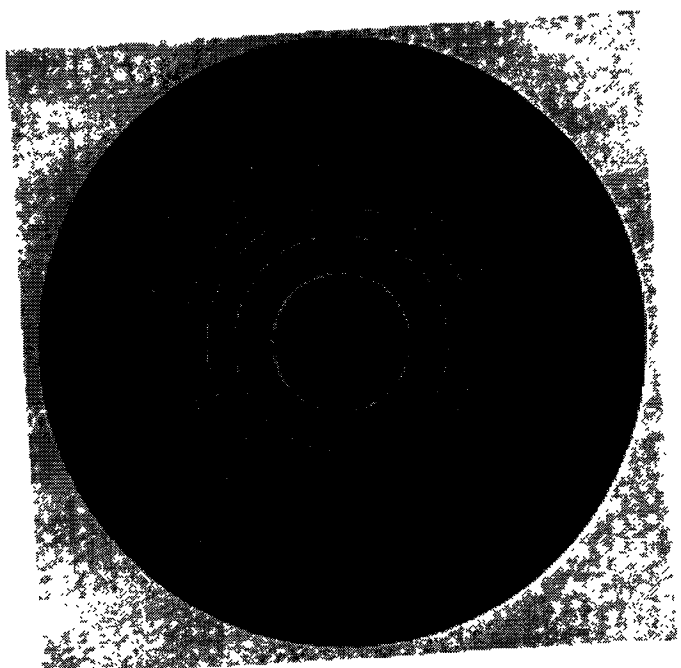
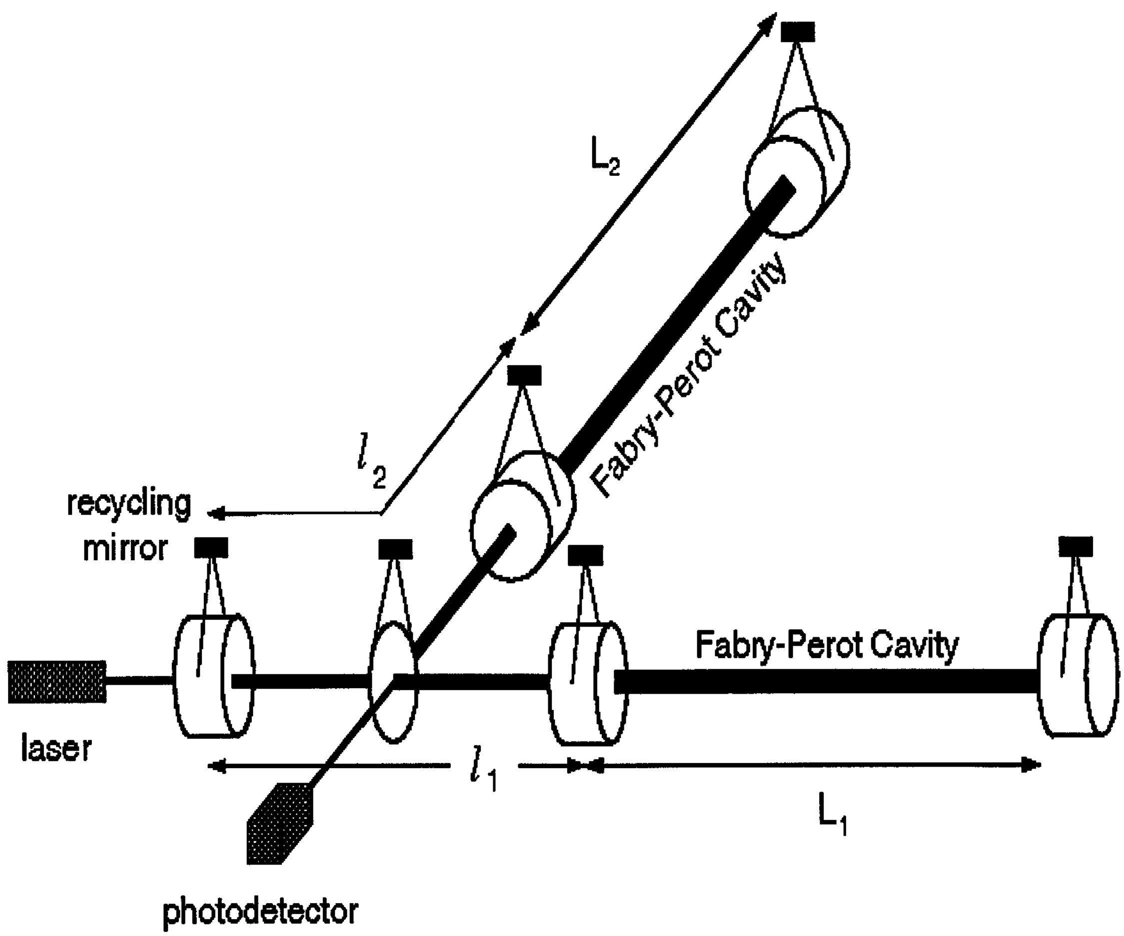


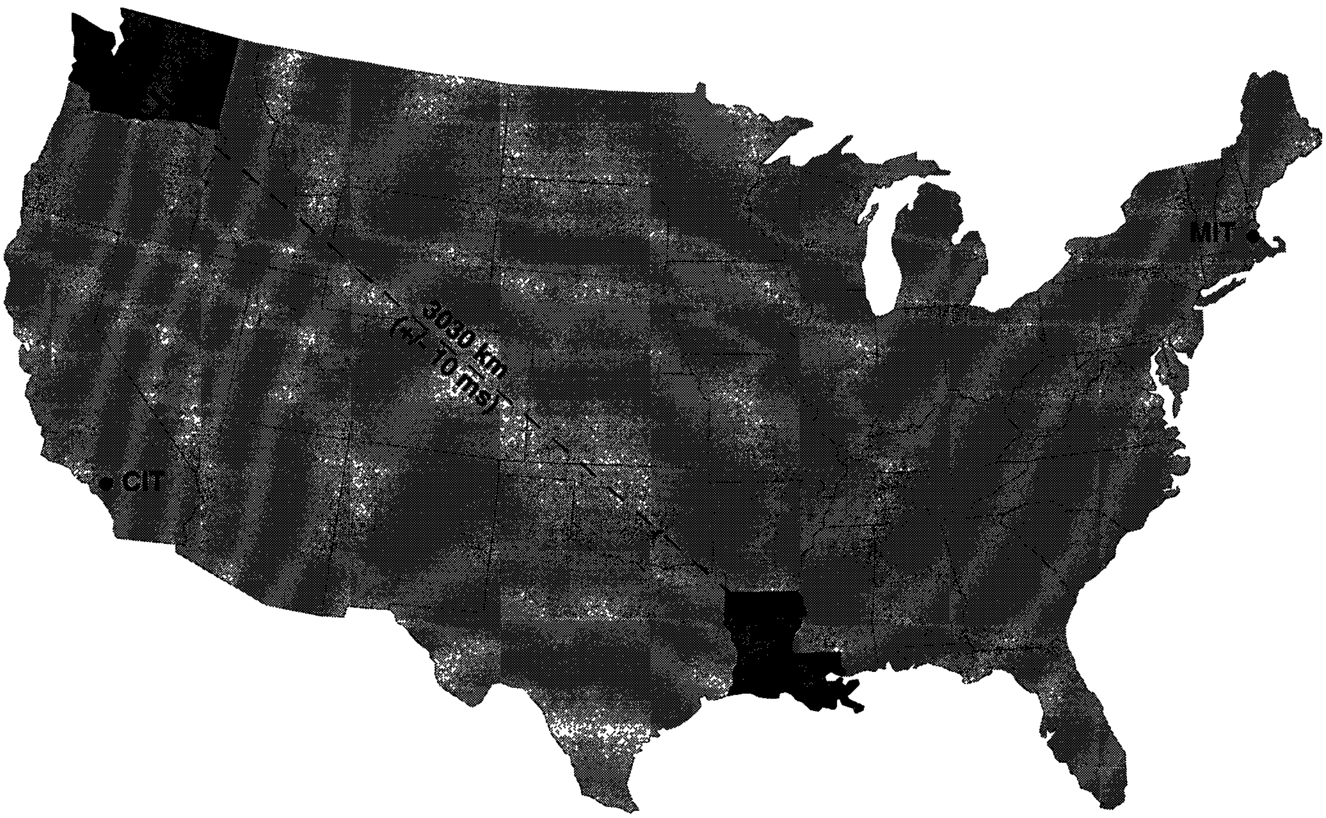
Fig. 7.60. FABRY–PEROT fringes.

LIGO Interferometer Configuration



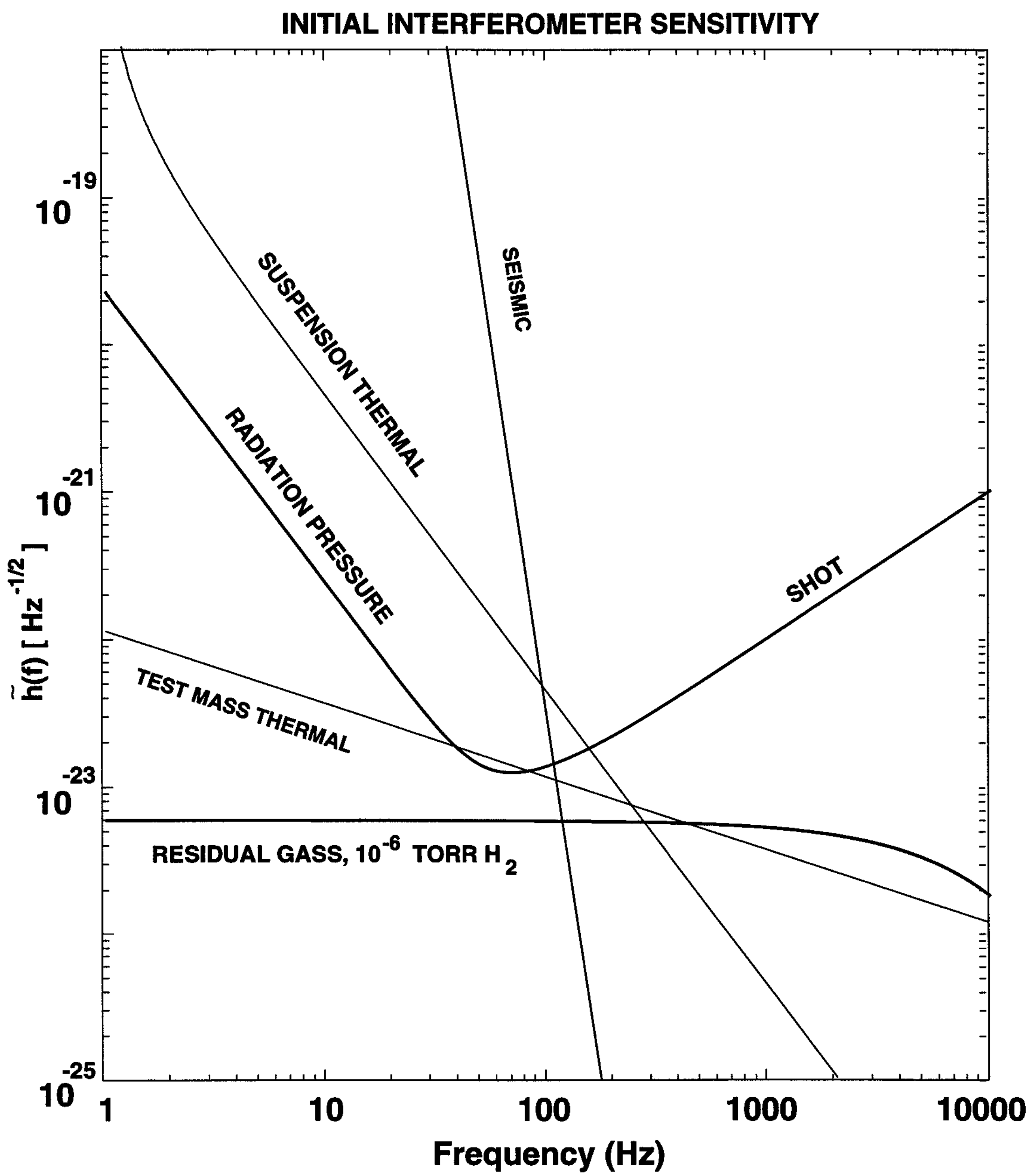
LIGO Sites

HANFORD, WASHINGTON

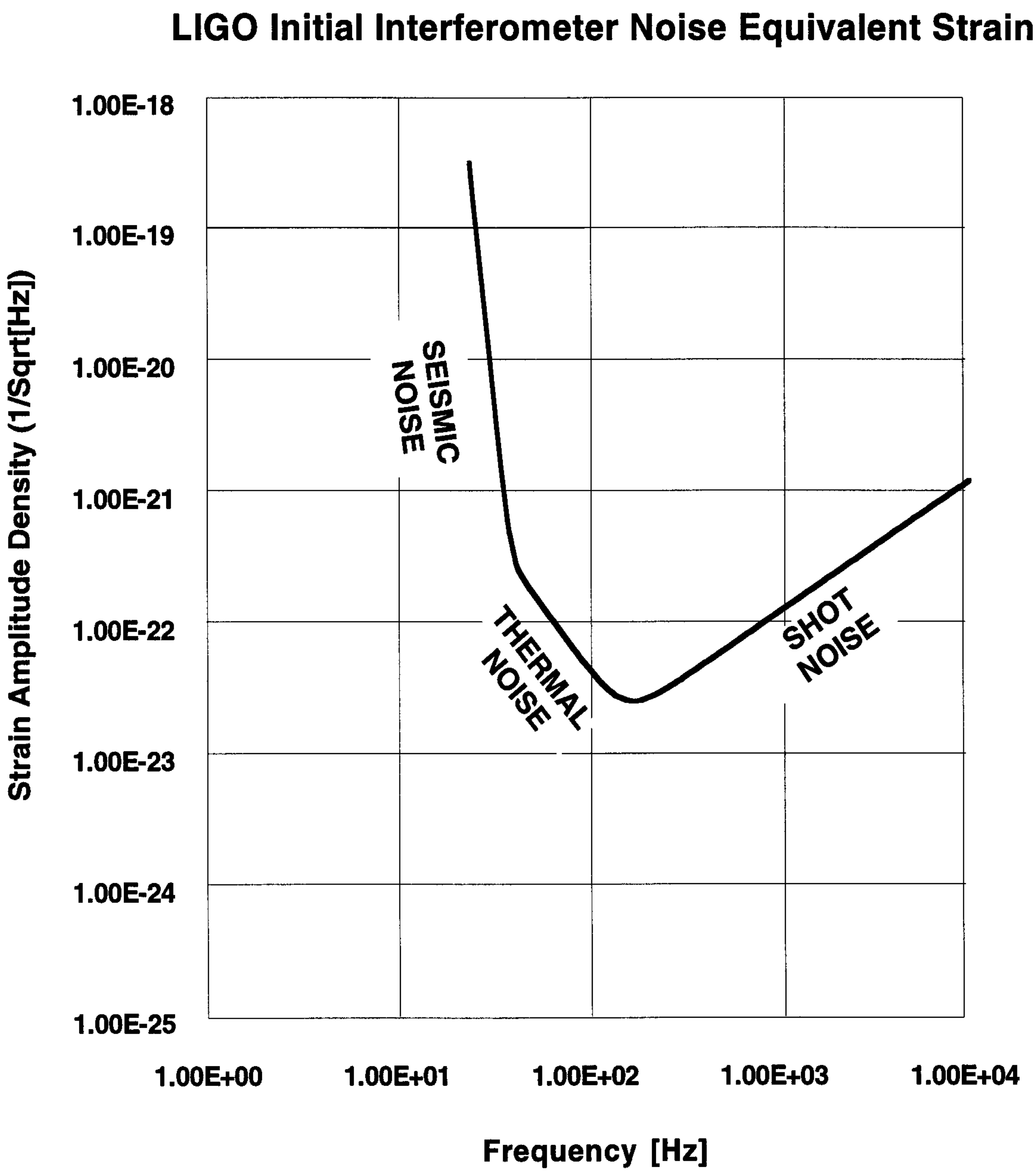


LIVINGSTON, LOUISIANA

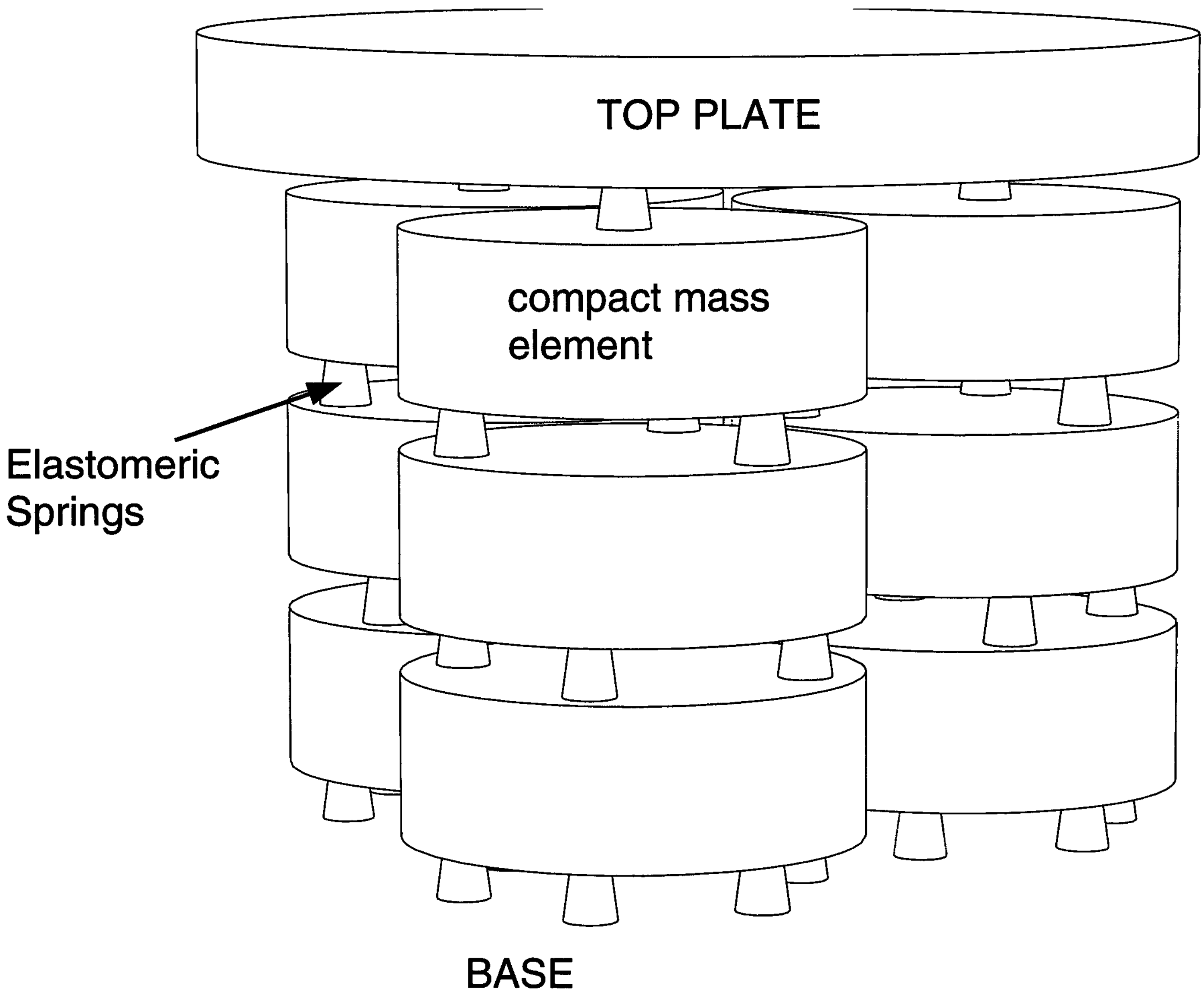
Initial Design Performance Goal



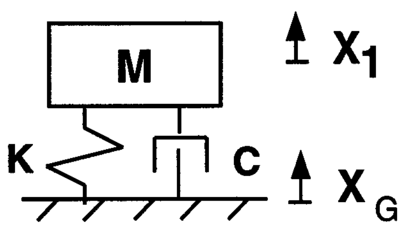
Initial Design Performance Goal

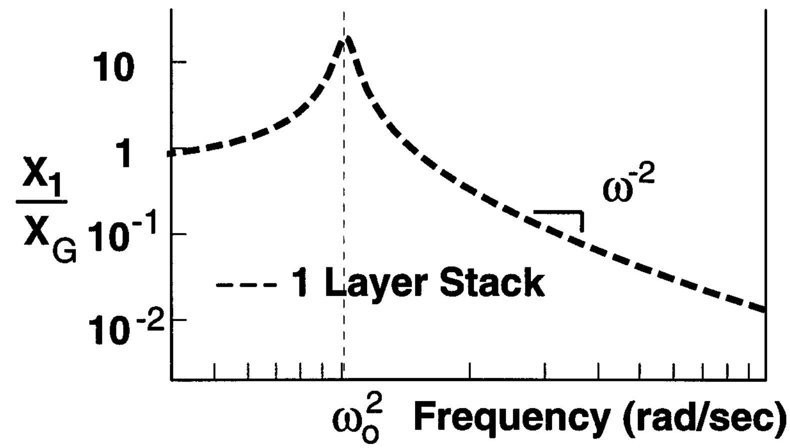


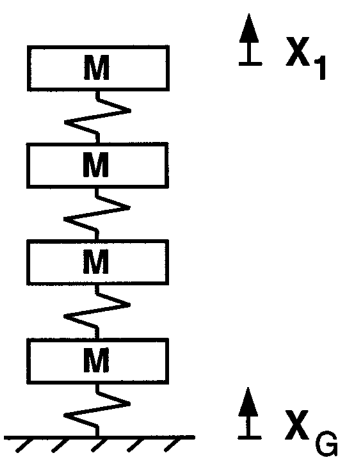
Seismic Isolation



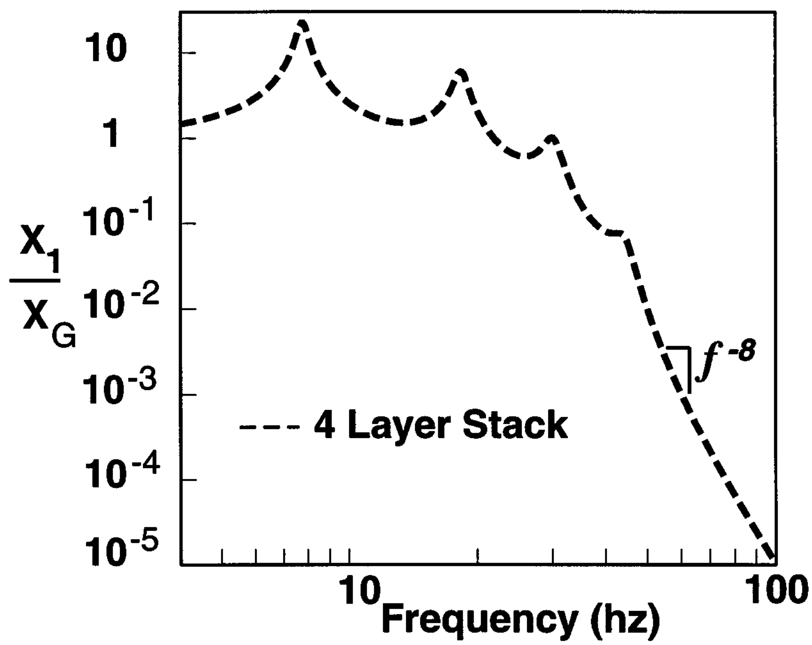
Seismic Isolation



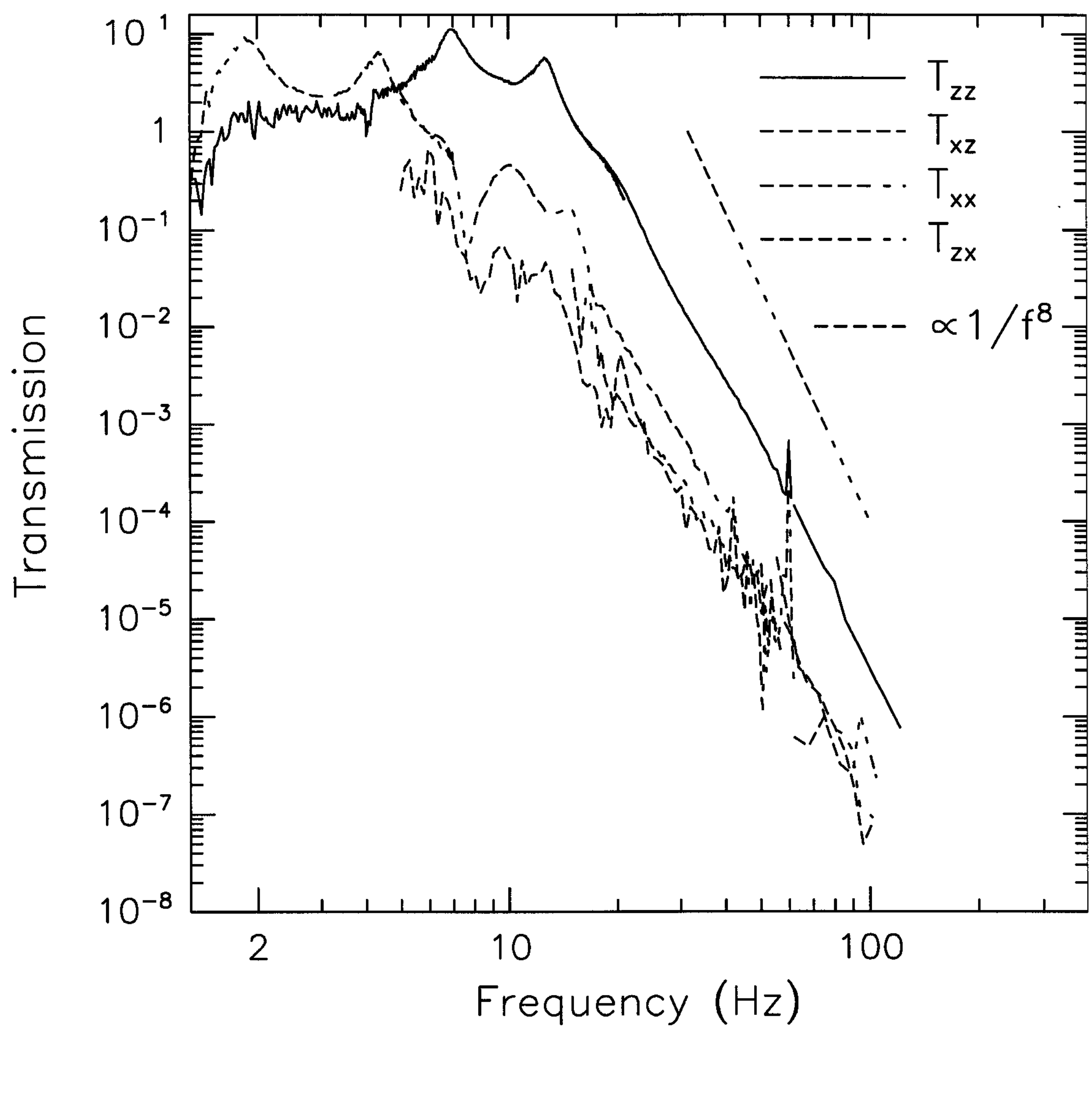




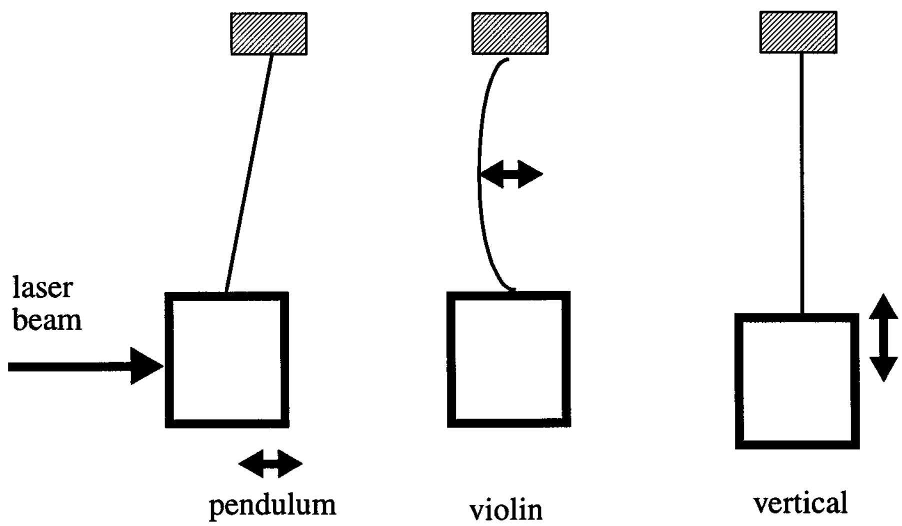
Simple Model of Mark 2 Stack Isolation (vertical)



Seismic Isolation



Suspension Thermal Noise



“Excess” Suspension Thermal Noise (Braginsky, Moscow)

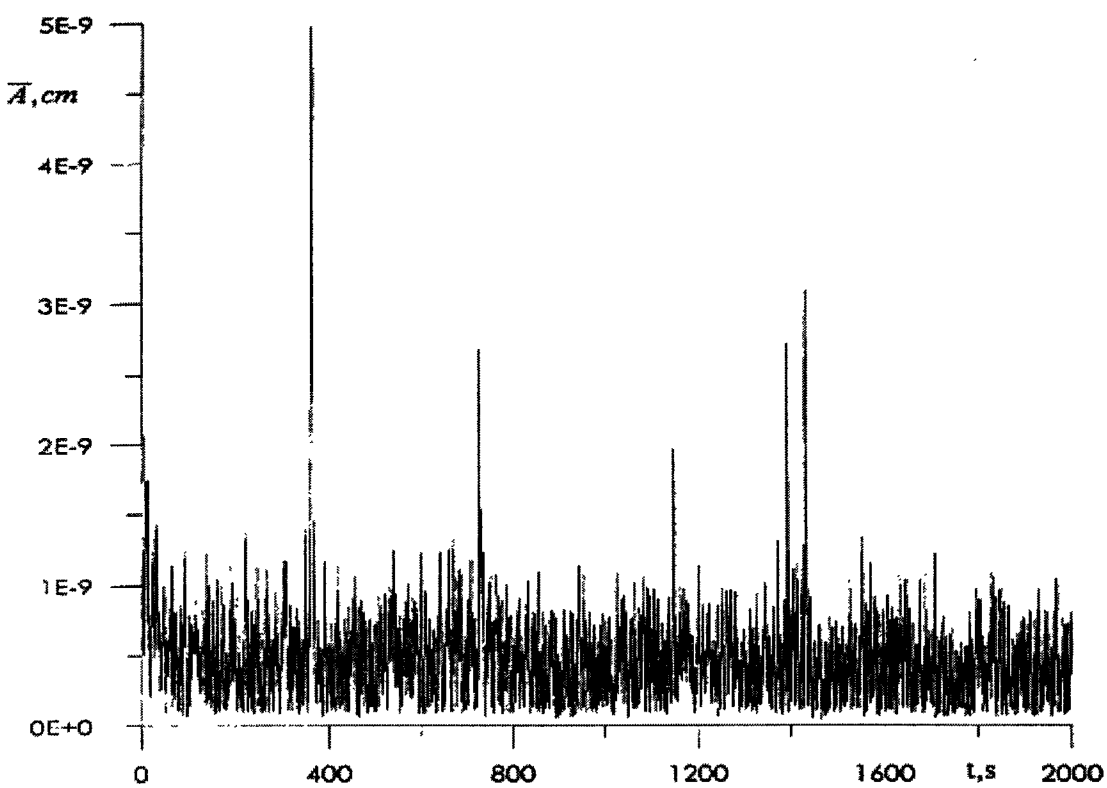
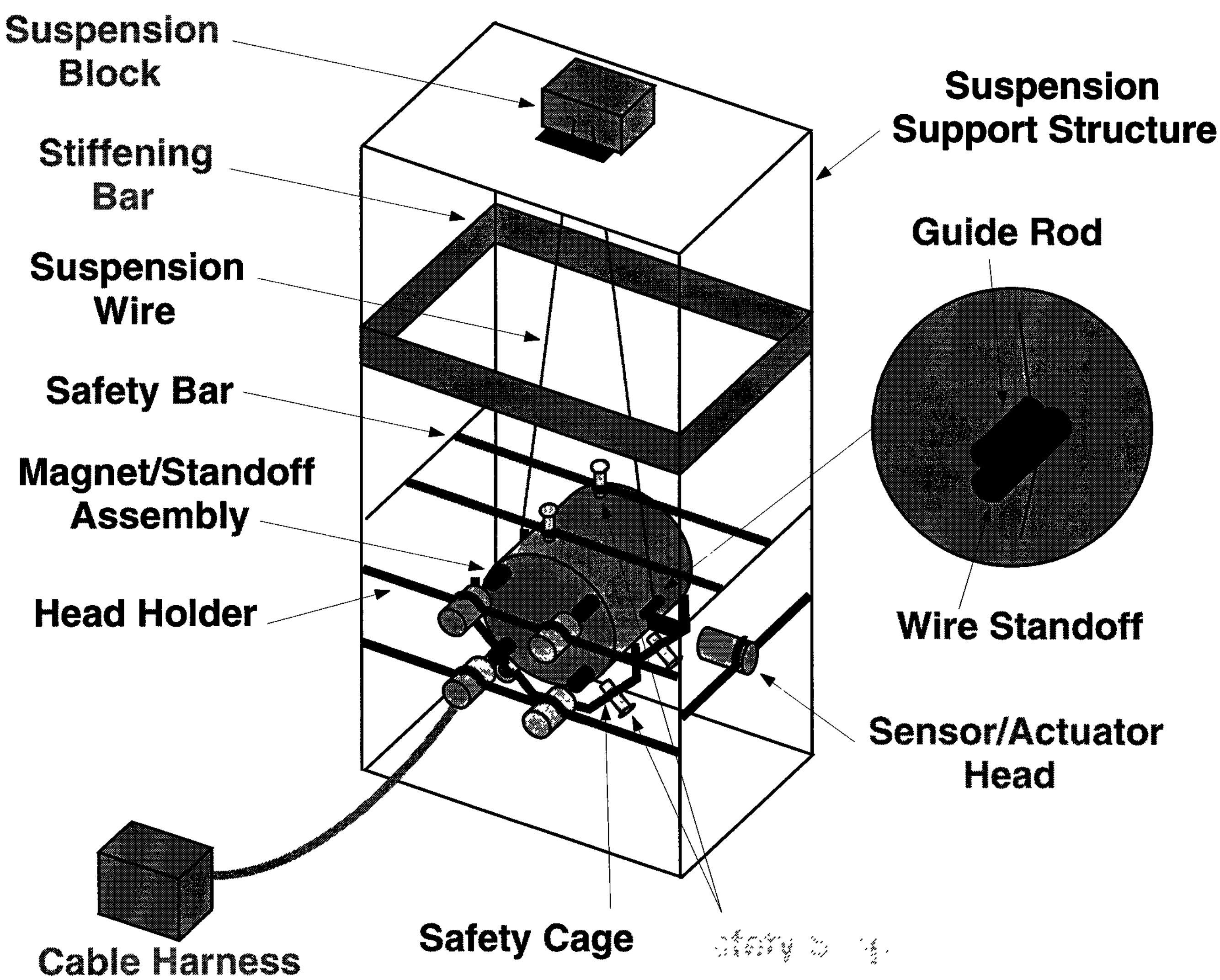
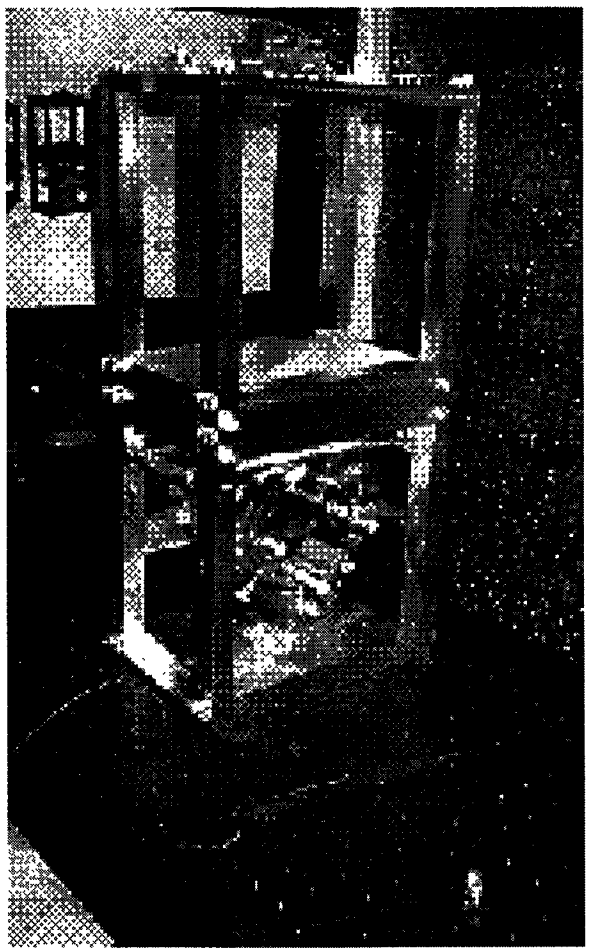


Fig. 5. Fragment of the record of noise oscillation of tungsten wire

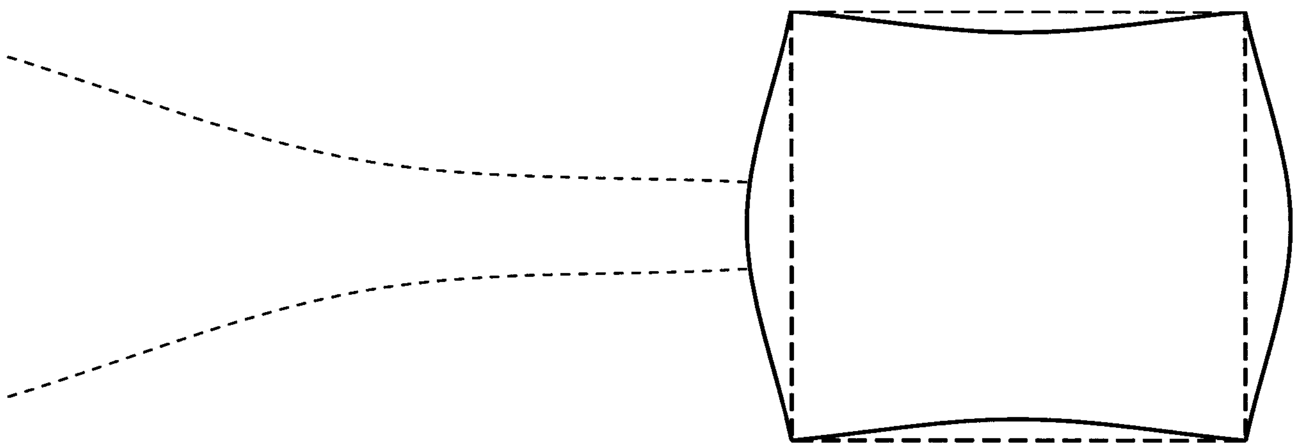
Test Mass Suspension



New Single Loop Suspension

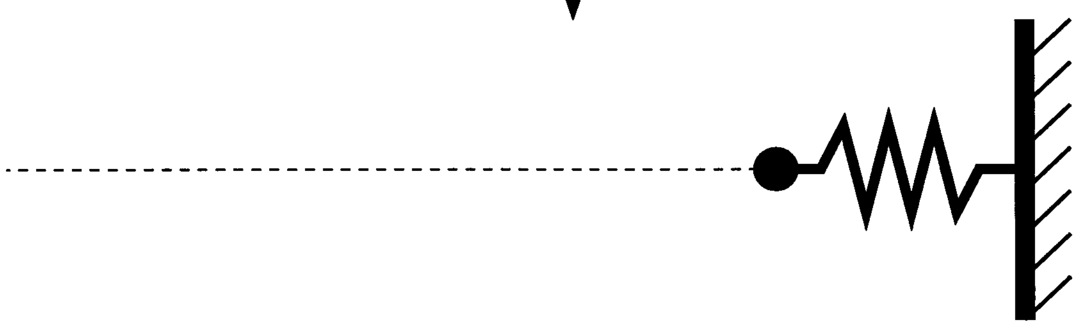


Test Mass Internal Thermal Noise



optical mode: $\psi(\rho,\theta,z)$
wave vector: $\vec{k}$

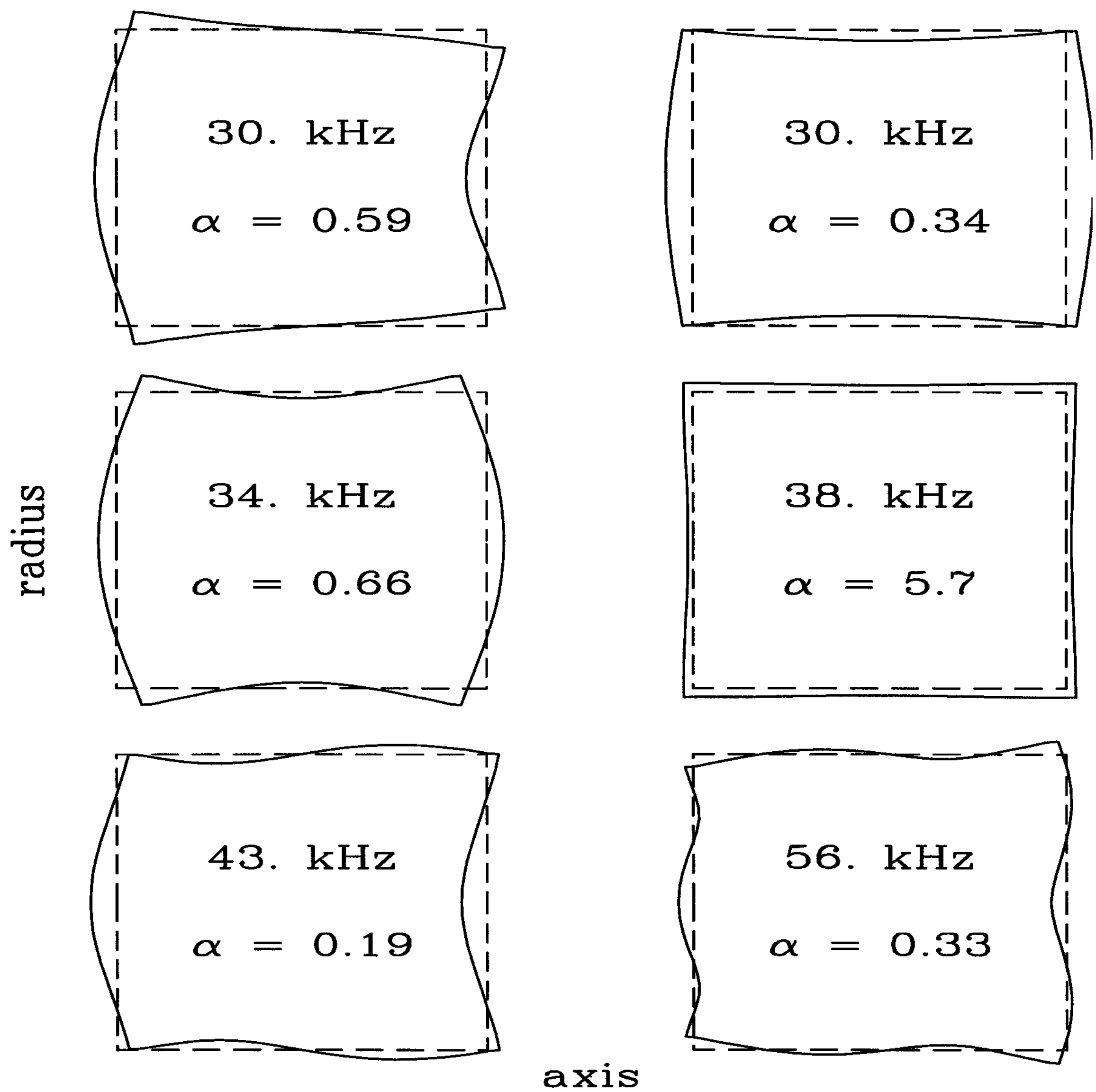
mirror mode: $\vec{u}(\rho,\theta,z)$
frequency: ω_n



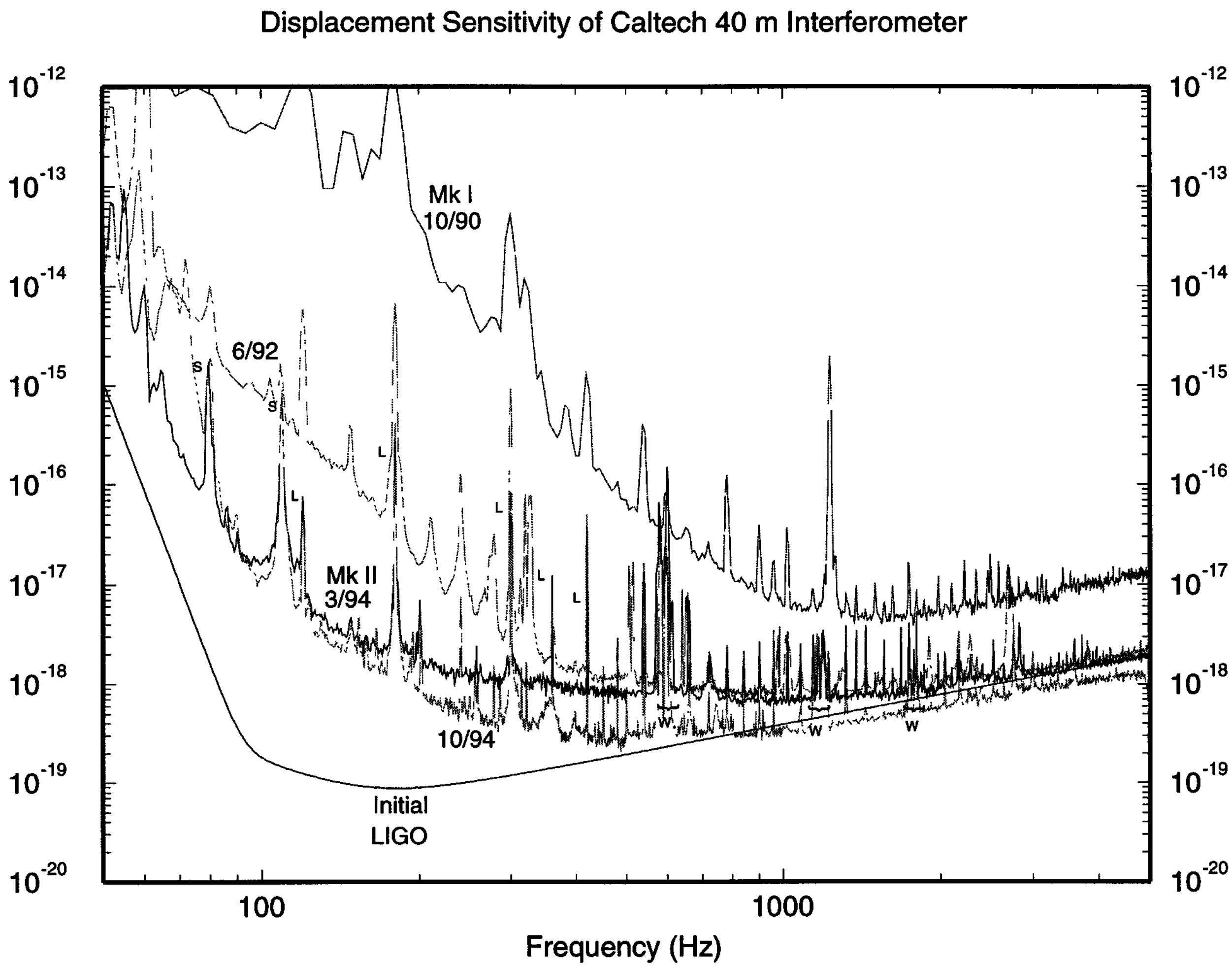
one-dimensional
laser beam
wave vector: $\vec{k}$

point mass on spring
mass: $\alpha_n m$
frequency: ω_n

Test Mass Internal Thermal Noise

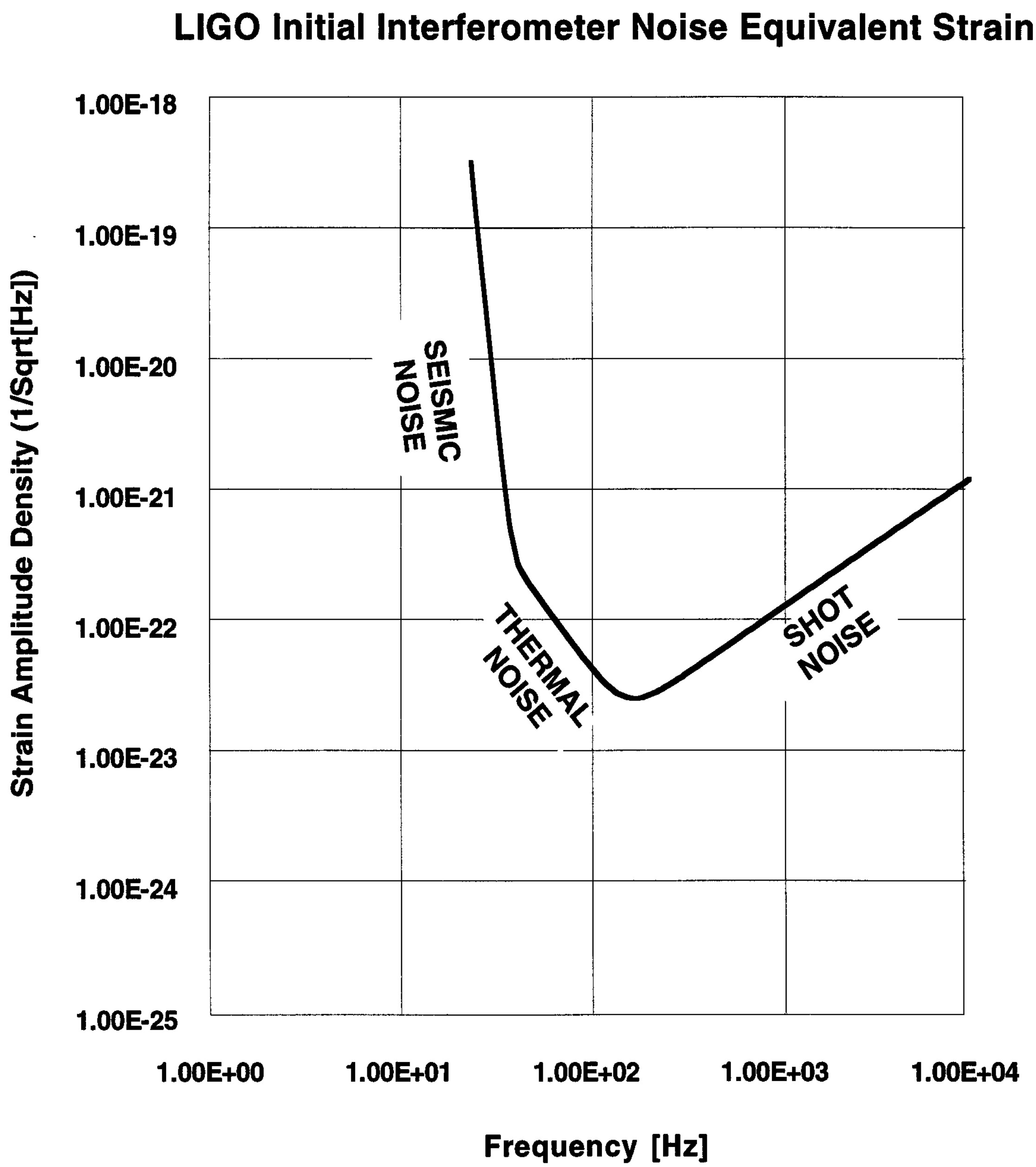


40 Meter Interferometer Displacement Noise R&D

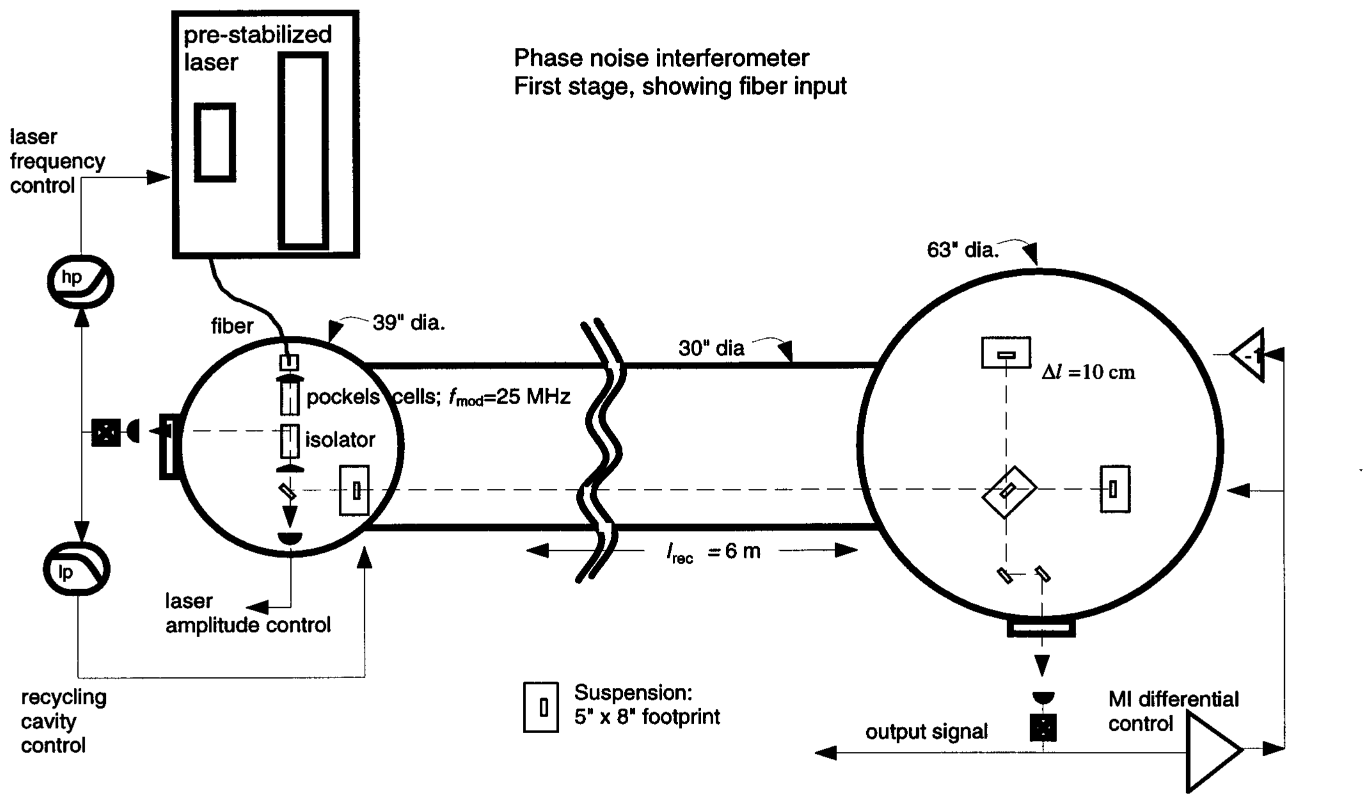


LIGO-G960225-00-M

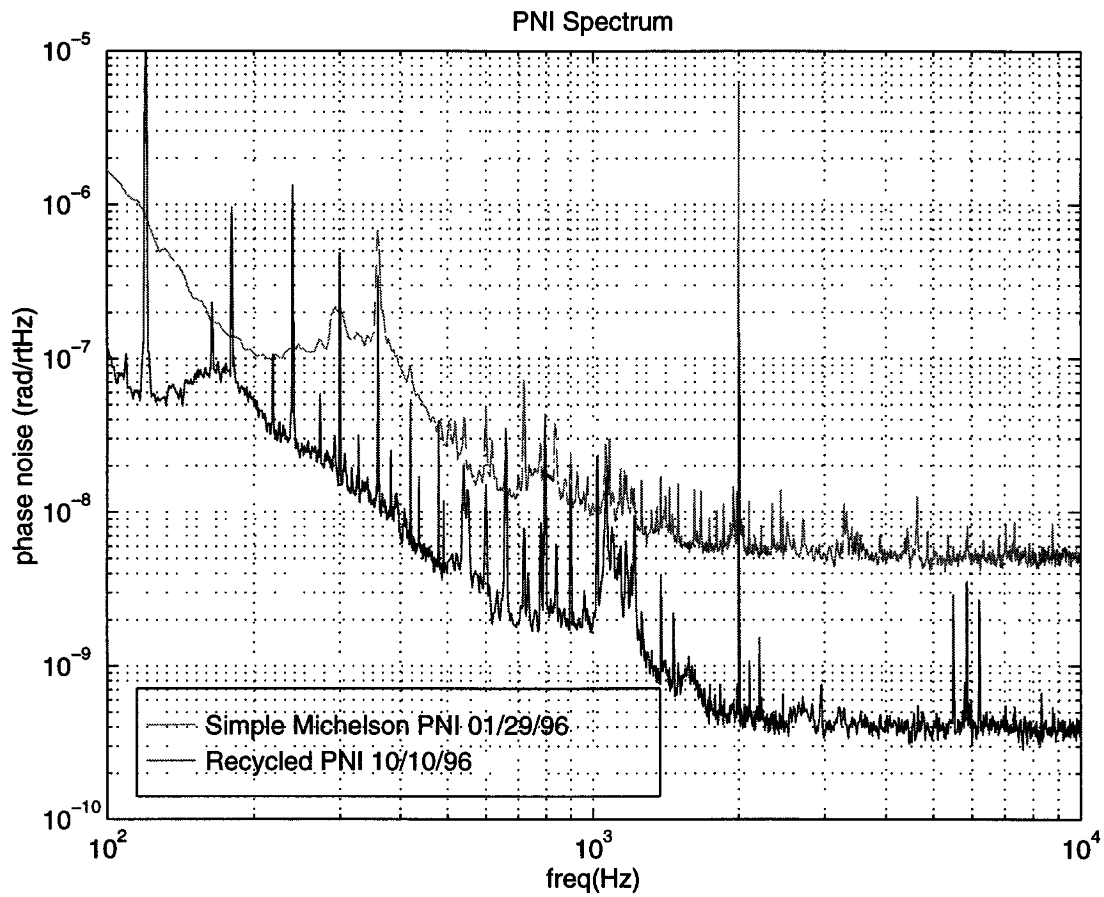
Initial Design Performance Goal



MIT Phase Noise Interferometer



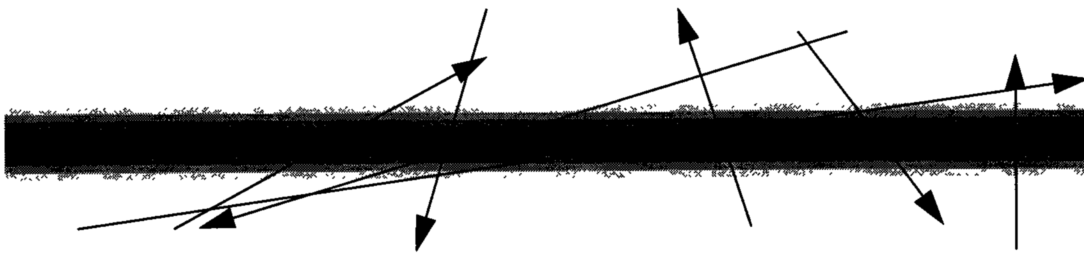
Latest Phase Sensitivity



This measurement is the best ever achieved by any group.

Vacuum System Requirements

Light must travel 4 km without attenuation or degradation



- index fluctuations in gas cause variations in optical path
  - pressure, polarizability, molecular speed of various species
  - light beam intensity distribution, coherence of effect

$$h(f) \approx 4\pi\alpha\left(\frac{2\rho}{v_0 w_0 l}\right)^{\frac{1}{2}}$$

- requirement for quality of vacuum in 4 km tubes from this
  - H_2 of 10^{-6} torr initial, 10^{-9} torr ultimate
  - H_2O of 10^{-7} torr initial, 10^{-10} ultimate
- vacuum system, 1.22 m diameter, ~10,000 cubic meters

LIGO Construction Status

- Construction of the $296 million Project is 34% complete
- Contracts in place commit additional 1/3 of the Project
- Hanford concrete work complete, buildings under construction
- Livingston grading complete, building contracts start this month
- Beam tube fabrication in progress, ~70 of 800 sections fabricated
- Beam tube installation in Hanford has begun
- Vacuum equipment (tanks, gate valves, pumps,...) is ~50% complete
- Detector laser and optics fabrication is underway
- Detector controls fabrication is underway
- Validating R&D on displacement sensitivity, phase sensitivity and configuration is in final stages

After Construction

››Physics observations at initial sensitivity commence in late 2001

››R&D for enhancements to initial interferometers and for entirely new advanced detectors begins in 1997 with first enhancements under construction in 2001

››European Italian/French Virgo 3 km interferometer operational in 2001 near Pisa

››German/UK 600 m interferometer under construction near Hannover

››Japanese TAMA interferometer under review

››LIGO Project will form into a LIGO Laboratory and a larger LIGO Collaboration in a process beginning this winter