LIGO's Thermal Noise Interferometer

Progress and Status

Eric Black, Ken Libbrecht, Luca Matone,
Shanti Rao, Kevin Schulz
LIGO, Caltech

Seiji Kawamura
TAMA, Tokyo

LIGO-G010031-00-D

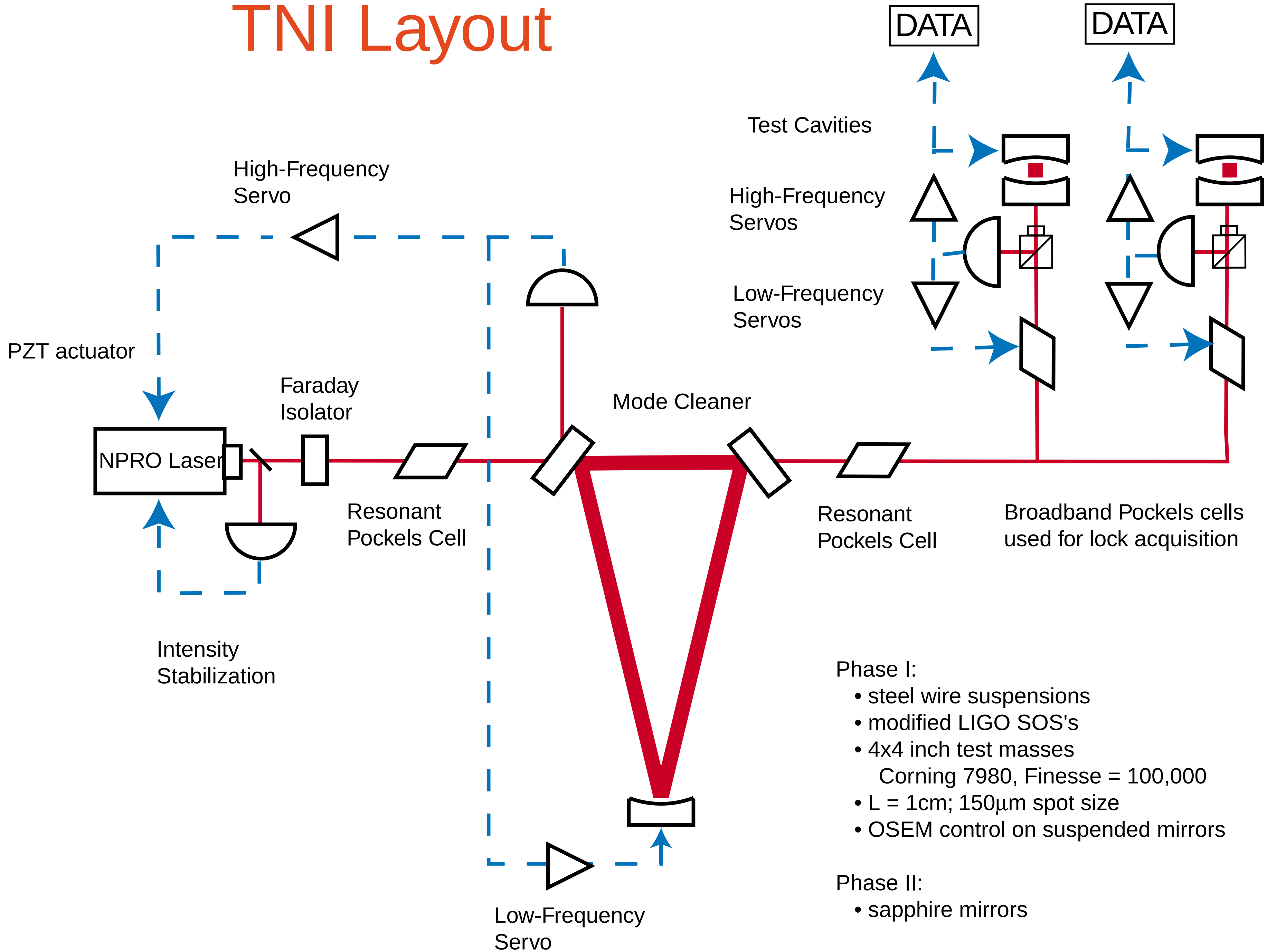
2001 Conference on Gravitational Waves and Their Detection, Aspen CO

TNI Objectives

- Study the physics of fundamental noise sources
  - ⇒ Isolate and study noise sources in mirrors and suspensions
  - ⇒ Test existing thermal noise models in very low-loss systems using a small spot size
  - ⇒ Characterize non-Gaussian noise in mirrors and suspensions

- Part of a larger program that includes
  - ⇒ Thermal Noise Interferometer
  - ⇒ Photothermal noise experiment
  - ⇒ Observation of SQL

TNI Layout

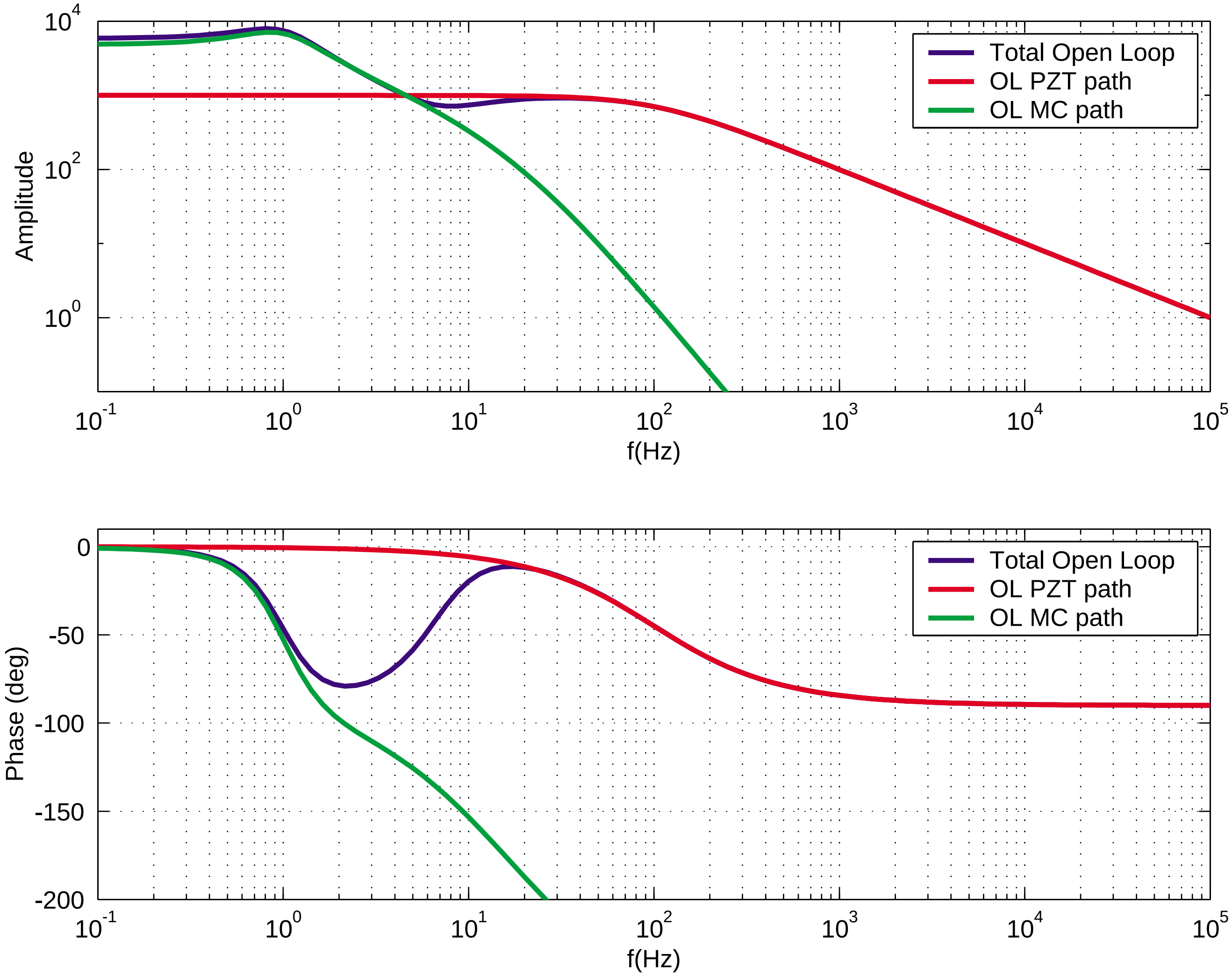


Phase I:

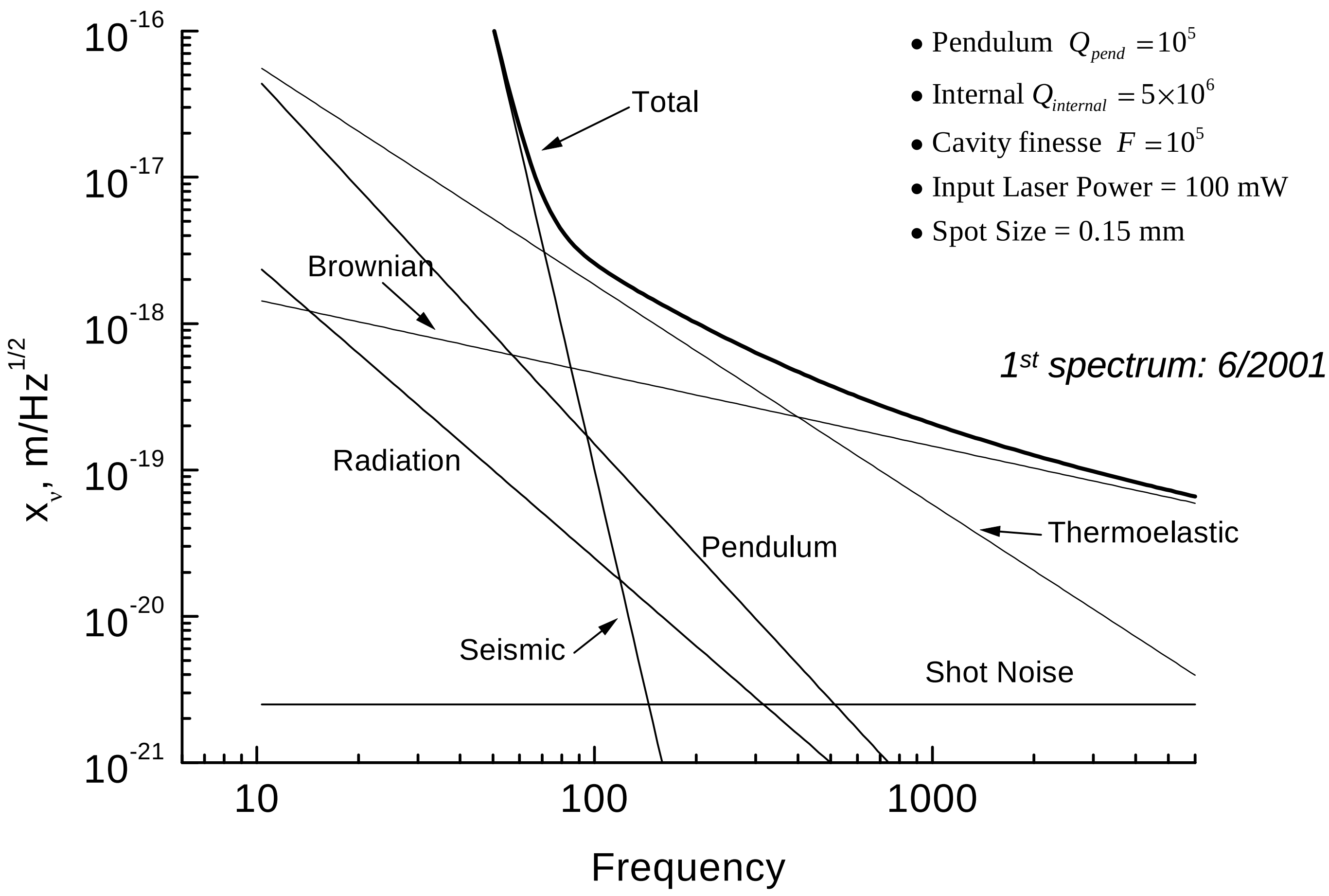
- steel wire suspensions
- modified LIGO SOS's
- 4x4 inch test masses
  Corning 7980, Finesse = 100,000
- L = 1cm; 150µm spot size
- OSEM control on suspended mirrors

Phase II:

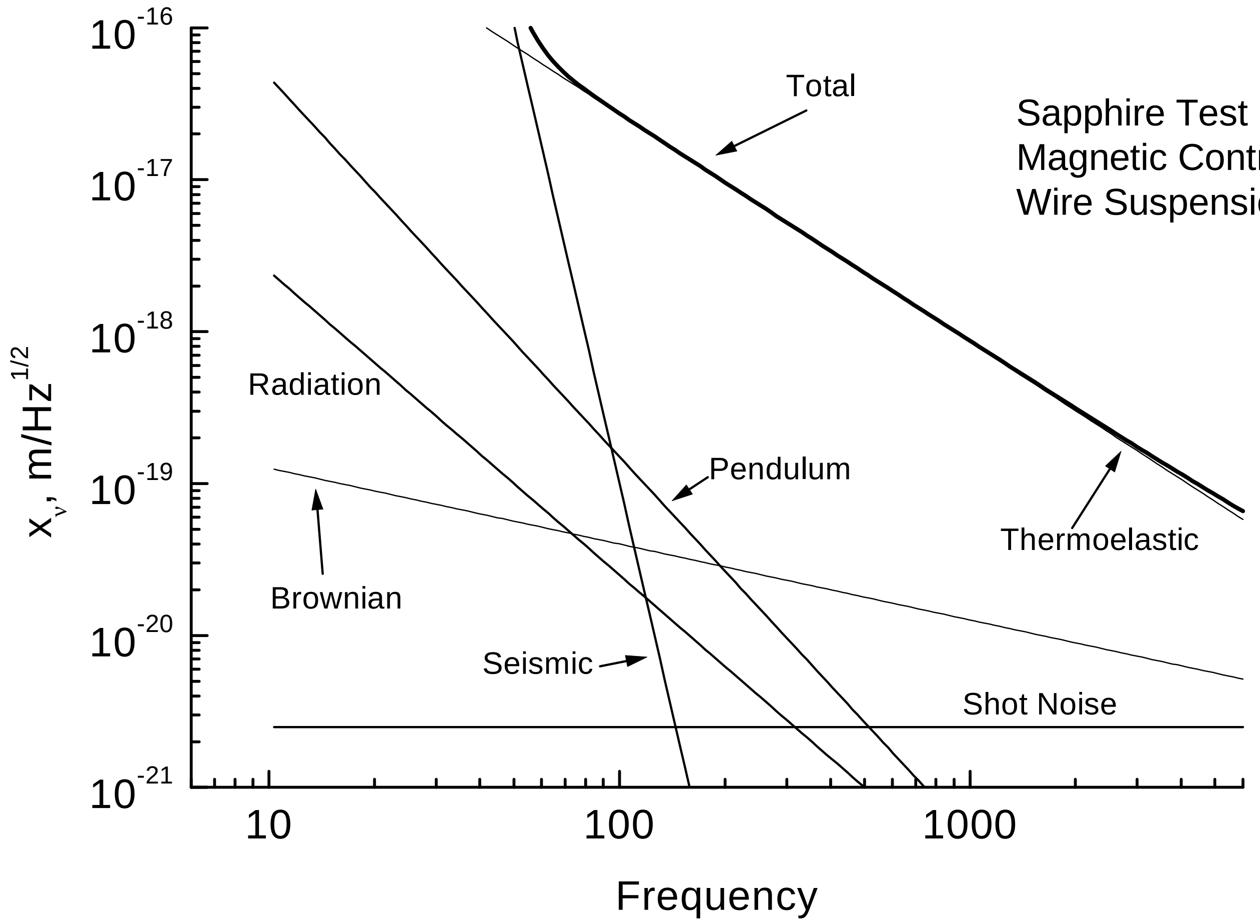
- sapphire mirrors


Amplitude
10^4
10^2
10^0
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
f(Hz)
Total Open Loop
OL PZT path
OL MC path
Phase (deg)
0
-50
-100
-150
-200
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
f(Hz)
Total Open Loop
OL PZT path
OL MC path

TNI Phase I Expected Spectrum

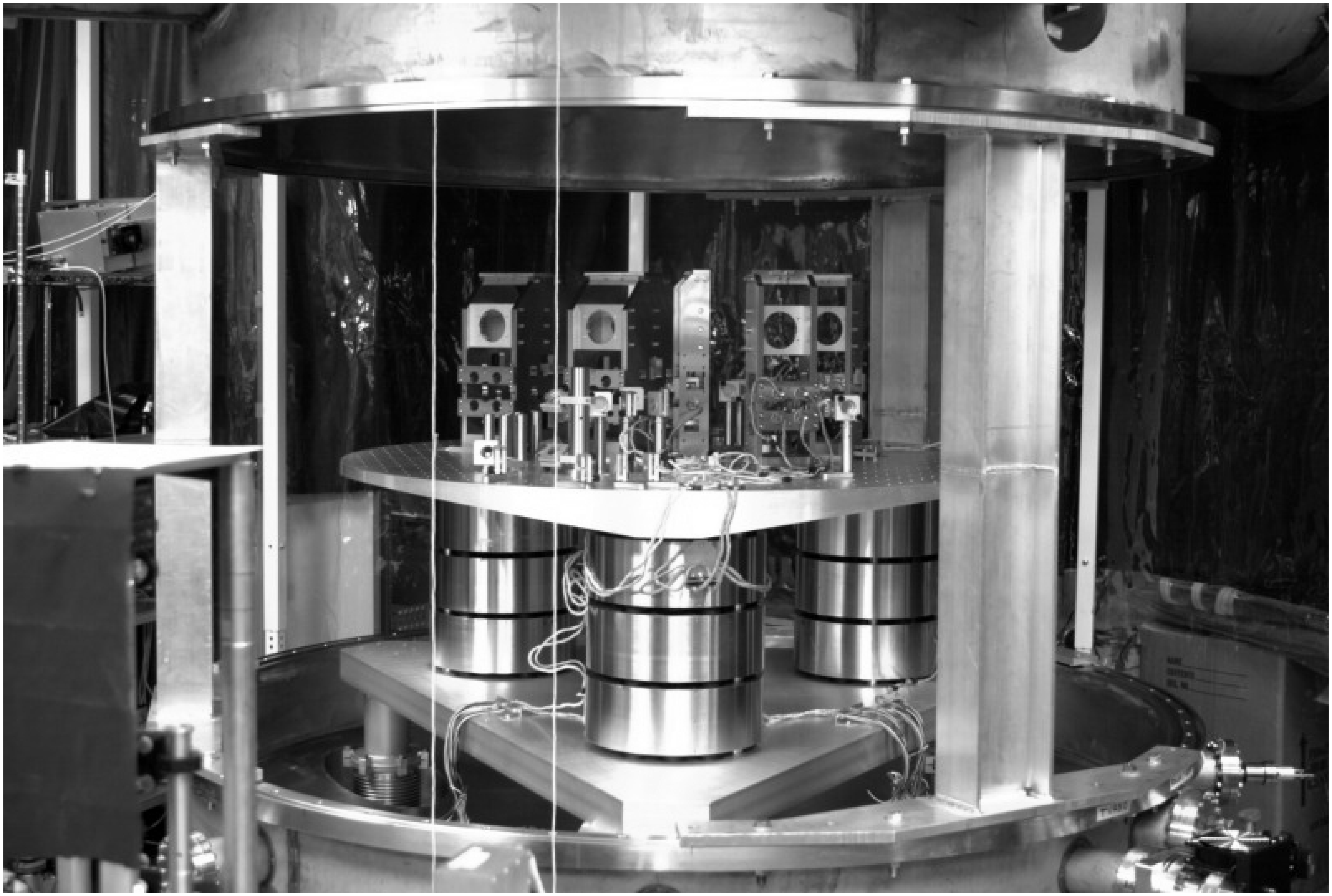


TNI Phase II Expected Spectrum



Sapphire Test Masses
Magnetic Controls
Wire Suspensions

TNI View inside vacuum chamber



Progress

- High finesses achieved in both the mode cleaner and one arm cavity
- Mode cleaner successfully locked in final (?) configuration
- Arm cavity locked using laser’s PZT input

Remaining tasks before first spectrum

- Replace laser (pathological behavior)
- Lock arm cavity using broadband Pockels cell
- Lock second arm cavity

Observations on lock acquisition

- Naive bandwidth requirement: servo must be fast enough to "catch" while the cavity is resonant

$$\frac{1}{\tau} \approx \frac{2F}{\lambda} v_{mirror}$$

$$v_{mirror} \approx 1\frac{\mu m}{s}\,; \qquad \lambda \approx 1\mu m\,; \qquad F \approx 100{,}000;$$

$$\frac{1}{\tau} \approx 200kHz$$

Observe: successful lock acquisition for bandwidths $\leq 50kHz$

$\Rightarrow$ $1\mu m/s$ is the *maximum* mirror velocity.

$\Rightarrow$ F closer to 50,000.

Conclusions

- We are building a dedicated interferometer to study displacement noise in mirrors and suspensions.
- Most of the hardware is assembled, and all optics (7) are suspended and damped.
- Initial, lock-acquisition stage is nearly complete. Remaining: Switch PZT actuator to broadband Pockels cell on arm cavity lock.
- We anticipate a preliminary noise spectrum by June, 2001.