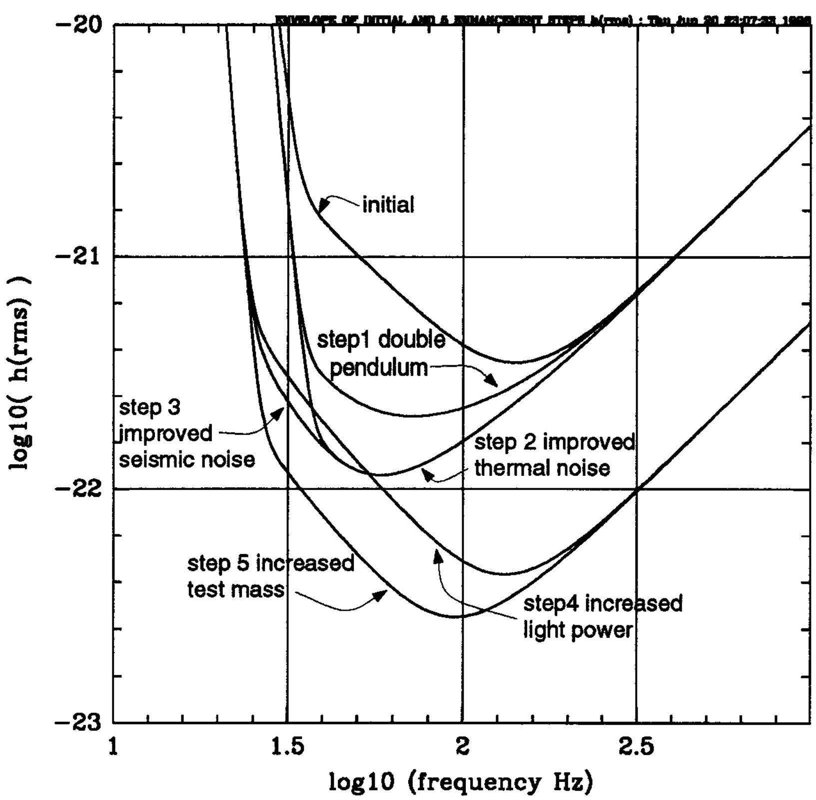
Double Suspensions

Science/Integration Meeting

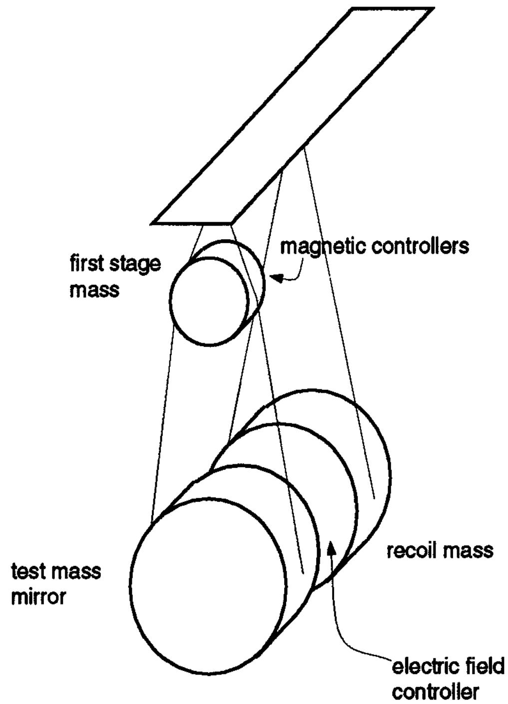
dhs 12 December 96

Possible performance improvement, 'Advanced Subsystems'



LIGO-G960xxx-00-D

Basic notion



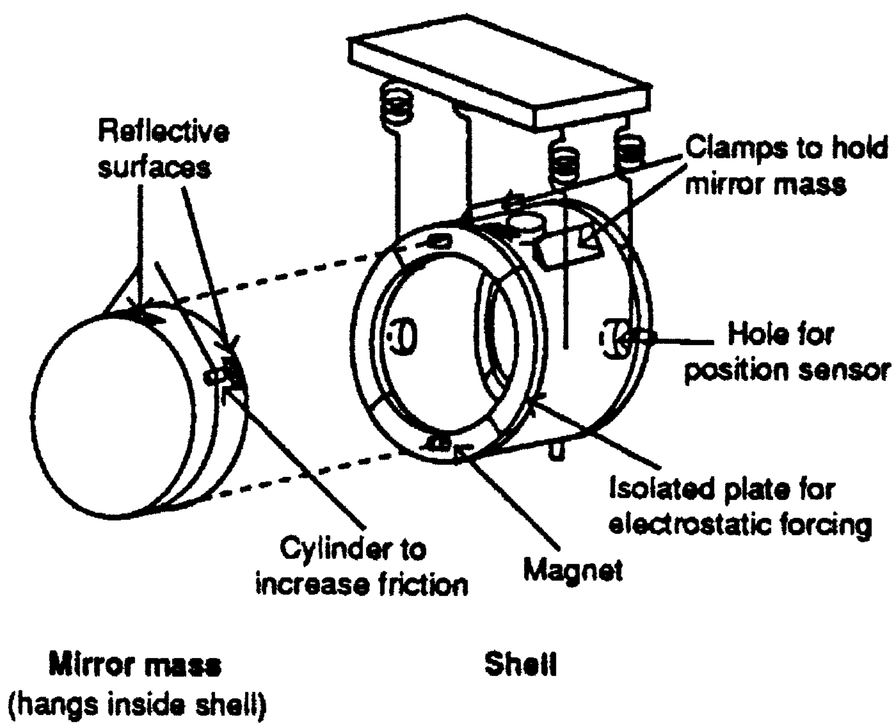
Remove mass one more layer from outside world

Advantages and Configurations

- Additional filtering for the thermal noise of the final stage of the vibration isolation system.
  - true for any high-Q first pendulum stage
  - marginal vertical isolation, unless vertical 'spring' integrated
- Reduction in the dynamic range of the feedback forces required to maintain the interferometer in a locked state, and the reduction of the controller noise, applied to the test mass.
  - forces are applied to upper mass, reducing TM rms motion
- The elimination of magnet attachment to the test mass providing a reduction in the mechanical loss of the internal modes and thereby a reduction in the internal thermal noise contribution.
  - assumes an electrostatic TM motor, or...
  - possibility of no driver on TM
- The elimination of the magnets on the test mass and their potential to cause magnetic domain jump noise (Barkhausen noise) and the undesirable sensitivity to fluctuating magnet fields in the LIGO laboratory.
  - same; could also reduce magnet size, but limited approach
- An improvement in the seismic isolation of the test mass by an additional factor of $\left(\frac{f_0}{f}\right)^2$
  - horizontal only
  - vertical XF of upper pendulum drives TM at 3×10^{-4}

Earlier efforts

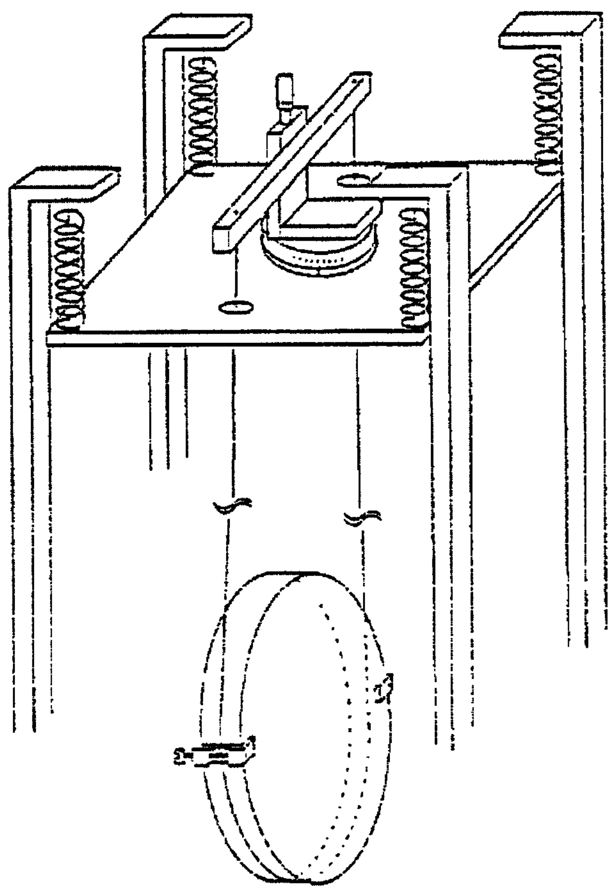
Stephens et al., MIT



- concentric masses, one as guard mass; magnetic actuators
- complicated but understood dynamics
- no interferometer tests

Earlier efforts

Garching 30m, first try

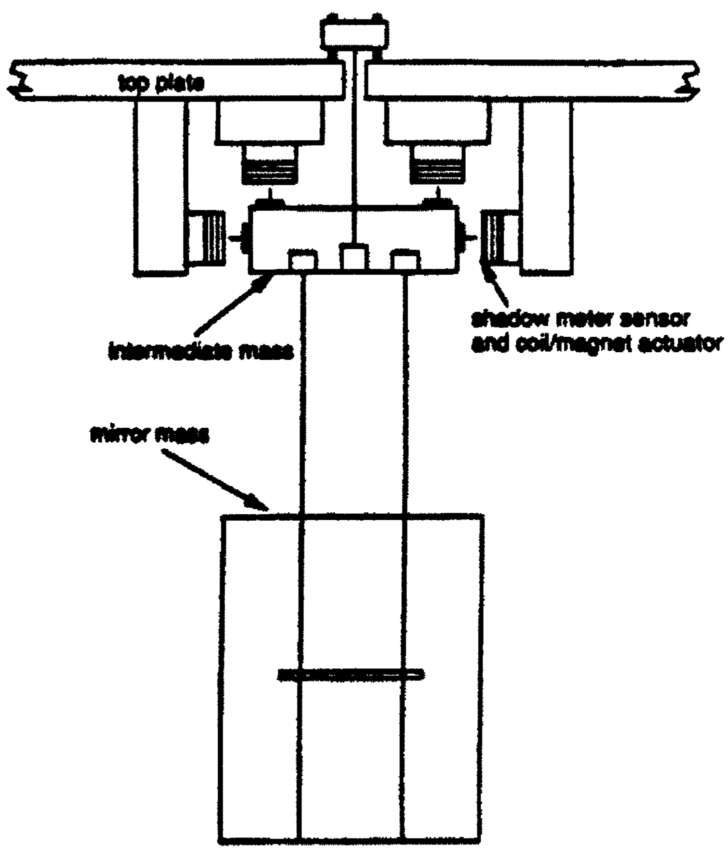


- coil spring suspension of upper optics table, local damping
- wire suspension for TMs, controllers referred to 'ground'
- XF in reasonable agreement with calculation
- ...no big improvement in performance, due to controller noise

Earlier efforts

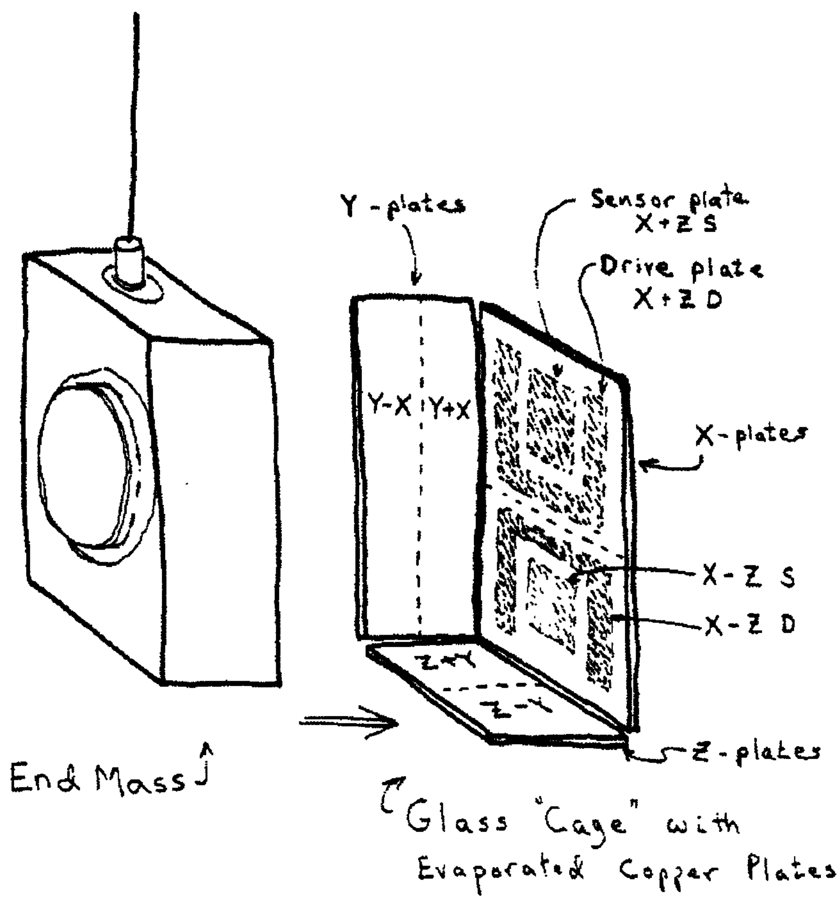
Glasgow

- straightforward; good performance
- design for GEO600 still in flux



Earlier efforts

Electrostatic controllers



- MIT 1.5m: functional, not linear
- starts at CIT, Glasgow

Configurations

Configuration chosen to optimize the

- seismic isolation (direct and indirect coupling) and
- controllability, as well as size constraints.

Steps:

- Assessment of the LIGO environment (Stanford and LIGO)
  - › seismic noise input,
  - › the external actuators, the
  - › transfer function of the passive seismic isolation stacks,
  - › optical system requirements on bandwidth, dynamic range
- Analysis of the present GEO double-pendulum design (Stanford and GEO)
- Choice of actual configuration (LIGO, input from GEO Stanford)
  - › number of suspended elements,
  - › choice of placement of actuators
  - › their references

Suspension materials, attachments

Thermal noise studies inextricably linked with suspensions

- basic research needed, many of the same players
  - Syracuse
  - Stanford
  - Moscow State
  - LIGO?
- suspension fibers
  - fiber geometries (rectangular section, multiple fibers)
  - fiber materials (silicon, fused quartz)
  - attachment means
- internal TM noise
  - measurements of materials (squeeze/release)
  - preparation of familiar materials
  - crystalline materials
- analytical work

Tests of thermal noise strategies require a suspension

- this research joins the suspension research in ifo tests
- possibility of direct measurement of thermal noise, or
- performance in a differentially-sensitive interferometer

Actuator techniques

Present magnet-coil system unattractive

- coupling to external magnetic fields
- Barkhausen noise

Two approaches to take advantage of dynamic range sharing

- reduce strength/existence of coupling
  - smaller magnets (limit...)
  - no actuators on bottom mass
- electrostatic motors
  - easy to shield
  - not so easy to build --- linearization, force

Nominal approach: electrostatics

- GEO will continue their development of an electrostatic actuator
  - possible element of the GEO suspension
  - LIGO requirements for force and dynamic range will be considered in the design and tests.
- LIGO will apply a systems approach to the development of requirements for the actuator for a LIGO-compatible actuator, and develop and test prototypes of actuators for test.

Prototype Tests

Intermediate tests

- Measurements of Q of pendulums, substrates
  - GEO and LIGO have equipment, experience
- Characterization of actuators, configurations
  - straightforward for expected properties, noise
  - requires small vacuum system, small ifo

High-sensitivity tests, possibly reduced scale mirrors

- requires interferometer of LIGO-like displacement sensitivity
- not necessarily two perpendicular arms
- propose to do in LIGO
- plan new MIT vacuum envelope to be compatible

Fabrication of LIGO-scale suspensions

- requires full-scale test of noise and actuator performance
- plan new MIT vacuum envelope to be compatible

Schedule

Significant Events	*Responsible*	*Date*
Control system requirements developed	Stanford	Fall 1997
GEO control system analyzed	GEO	Fall 1997
Configuration chosen	LIGO, GEO	Fall 1998
Suspension fibers research mature	Stanford, Syracuse	Fall 1998
Attachment system research mature	Syracuse, GEO, LIGO	Fall 1998
Actuator technology research mature	LIGO	Fall 1998
Integration/selection of technologies	All	Winter 1998
Initial prototype constructed	LIGO, Stanford	Spring 1999
Initial prototype testing finished	LIGO or GEO	Fall 1999
Final design ready for fabrication, unification with thermal noise research	LIGO, Stanford	Spring 2000
Final design installed in test interferometer	LIGO	Spring 2001
Interferometer tests finished	All	Spring 2002