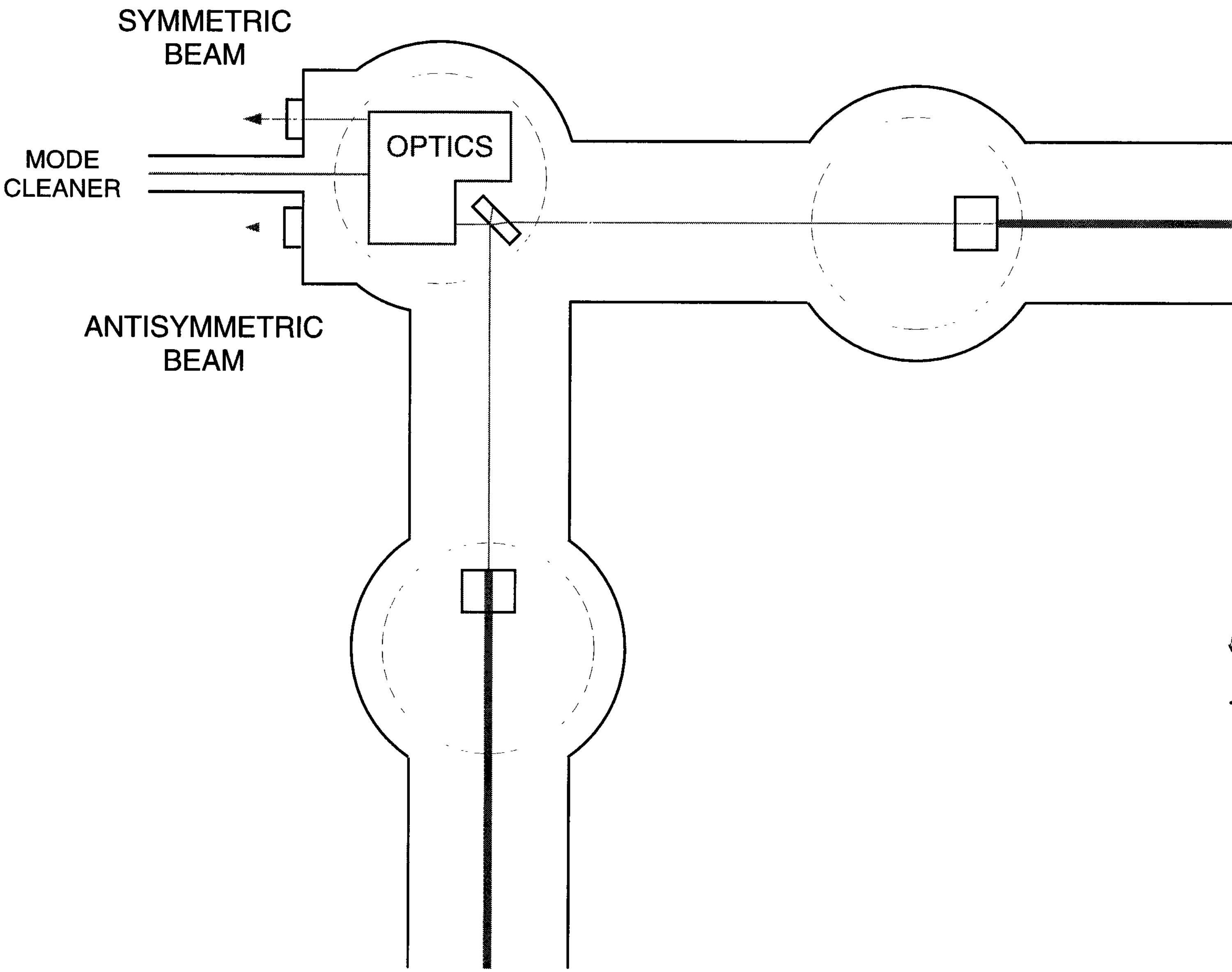
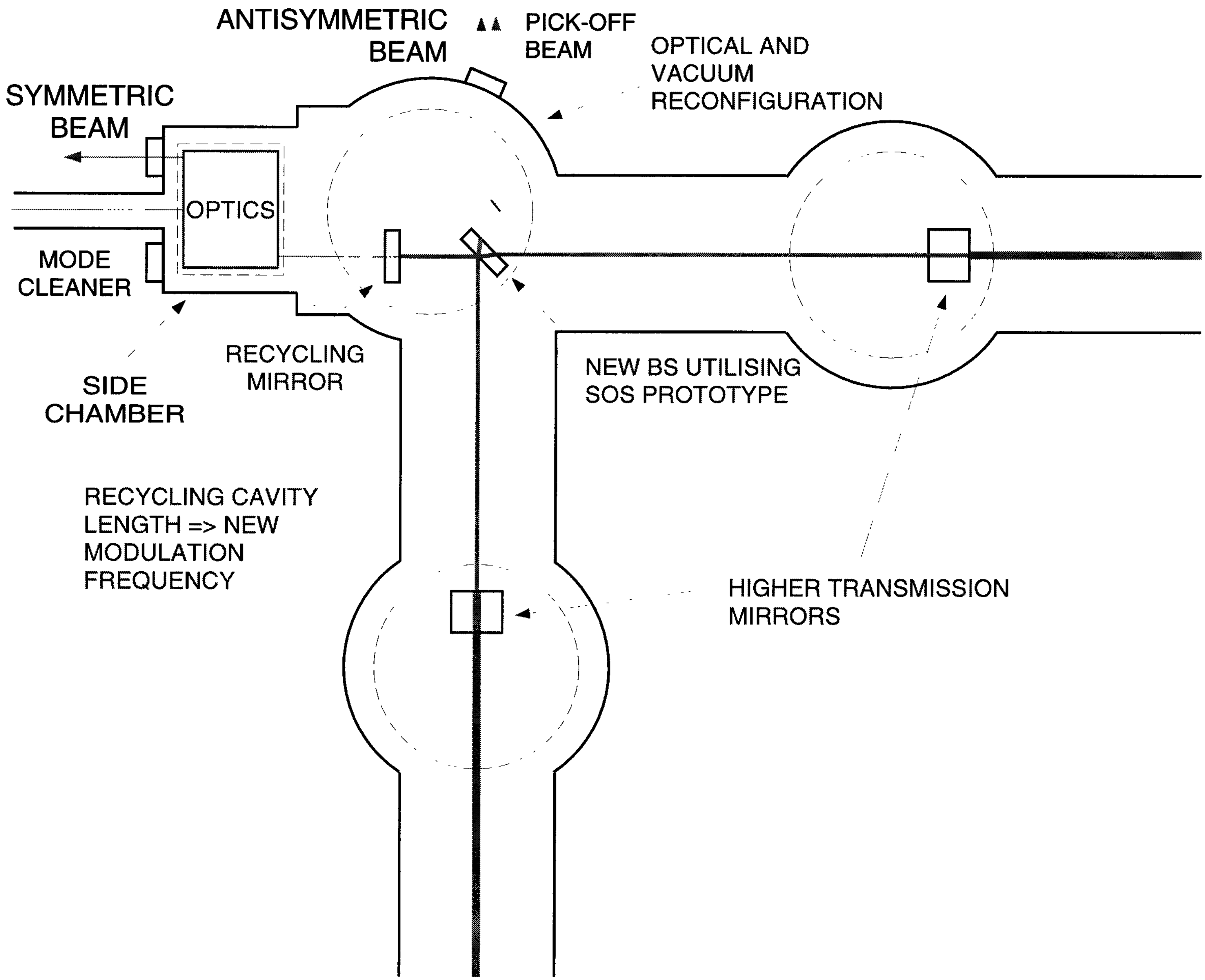
Science & Integration Meeting

Agenda

- Detector & R&D
  - ›› NPRO stabilization results — Mason/Savage
  - ›› Interferometer acquisition modeling results — Sievers
  - ›› FMI wavefront sensing results — Mavalvala/Sigg
  - ›› PNI status & plans — Fritschel
  - ›› 40m recycling status — Logan/Spero
  - ›› Core Optics Status: REO coating performance analysis — Jungwirth
  - ›› FFT modeling (20 min) — Kells
  - ›› DAQ prototype plan for 40m — Bork/Barker



JENNY LOGAN


ANTISYMMETRIC BEAM
PICK-OFF BEAM
OPTICAL AND VACUUM RECONFIGURATION
SYMMETRIC BEAM
OPTICS
MODE CLEANER
SIDE CHAMBER
RECYCLING MIRROR
NEW BS UTILISING SOS PROTOTYPE
RECYCLING CAVITY LENGTH => NEW MODULATION FREQUENCY
HIGHER TRANSMISSION MIRRORS

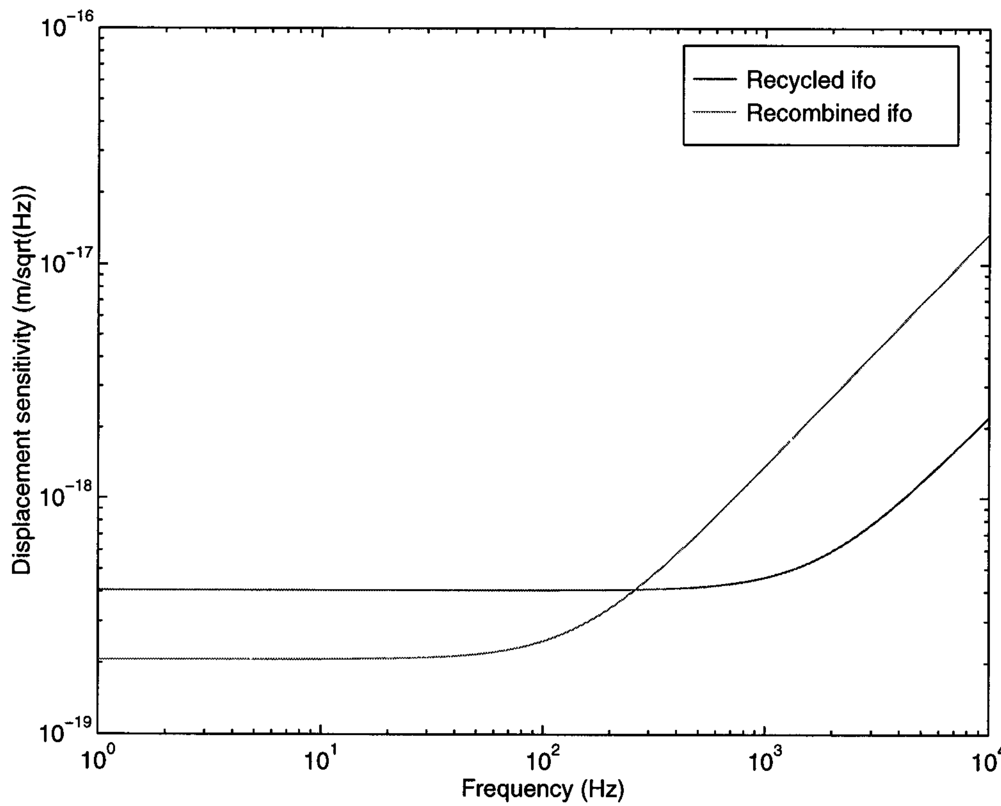
Optical Topology

- Planned recycling factor: 5

  ››due to difference in length scales between the 40m and LIGO, a more modest recycling factor has been chosen in order to keep the overall configuration similar to LIGO

- Mirror coatings have been apertured to make them more equivalent to LIGO; allowed the removal of apertures - a potential scattering surface

Predicted Shot Noise Sensitivity

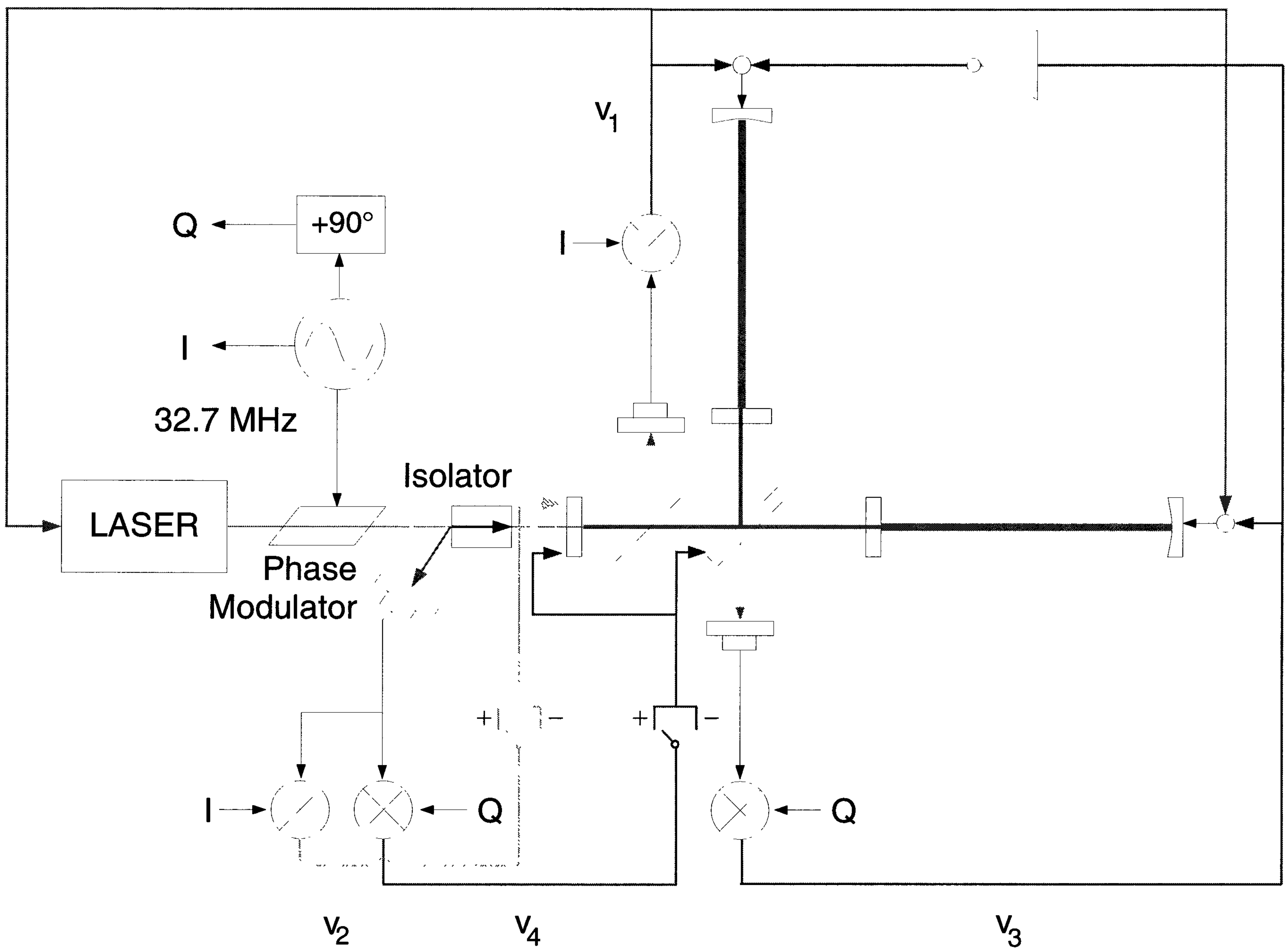


4

Control Scheme

- Lock acquistion design utilising SMAC (L. Sievers, D. Redding and L. Needles)
- Results from this have changed the baseline servo topology
- In the light of this some redesign of servos is currently underway
- Servo design utilising LIGO code

Optical and Servo Topology for the Recycled 40-m Interferometer



Deliverables from Recycling

- model validation
  - »both optics and servos
- a known and understood lock acquisition sequence
  - » how to acquire lock with relative ease (may require guided lock acquisition)
- set of diagnostics for troubleshooting
  - »how to hold lock robustly - understanding of mechanisms that cause the system to loose lock
  - »development of methodologies for standard noise tests; this will be naturally accompanied by work to lower the noise floor at the 40m
- an experienced crew

Summary of Results from Recombination Experiments on 40 m Interferometer

R. Spero; 12 December, 1996

Primary Goal	Achieved?
Acquire lock with asymmetry signal extraction	Yes!
Understand limiting noise sources	Partially
Lay groundwork for recycling	Yes

Other Results:

›› Lock sequencing (BS, CM, DM) and sign switching (of BS) first seen experimentally, later verified by calculations

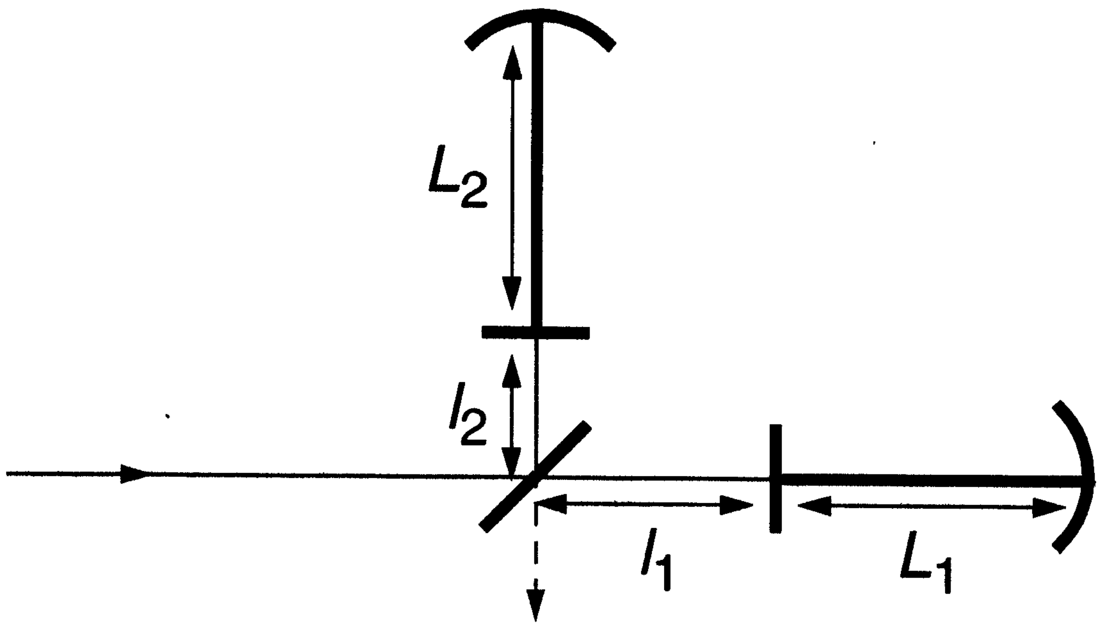
››Photocurrent from shot noise provides valuable check of interferometer calibration

›› Single-loop suspension and associated controller works well

›› Some progress in data collection and analysis

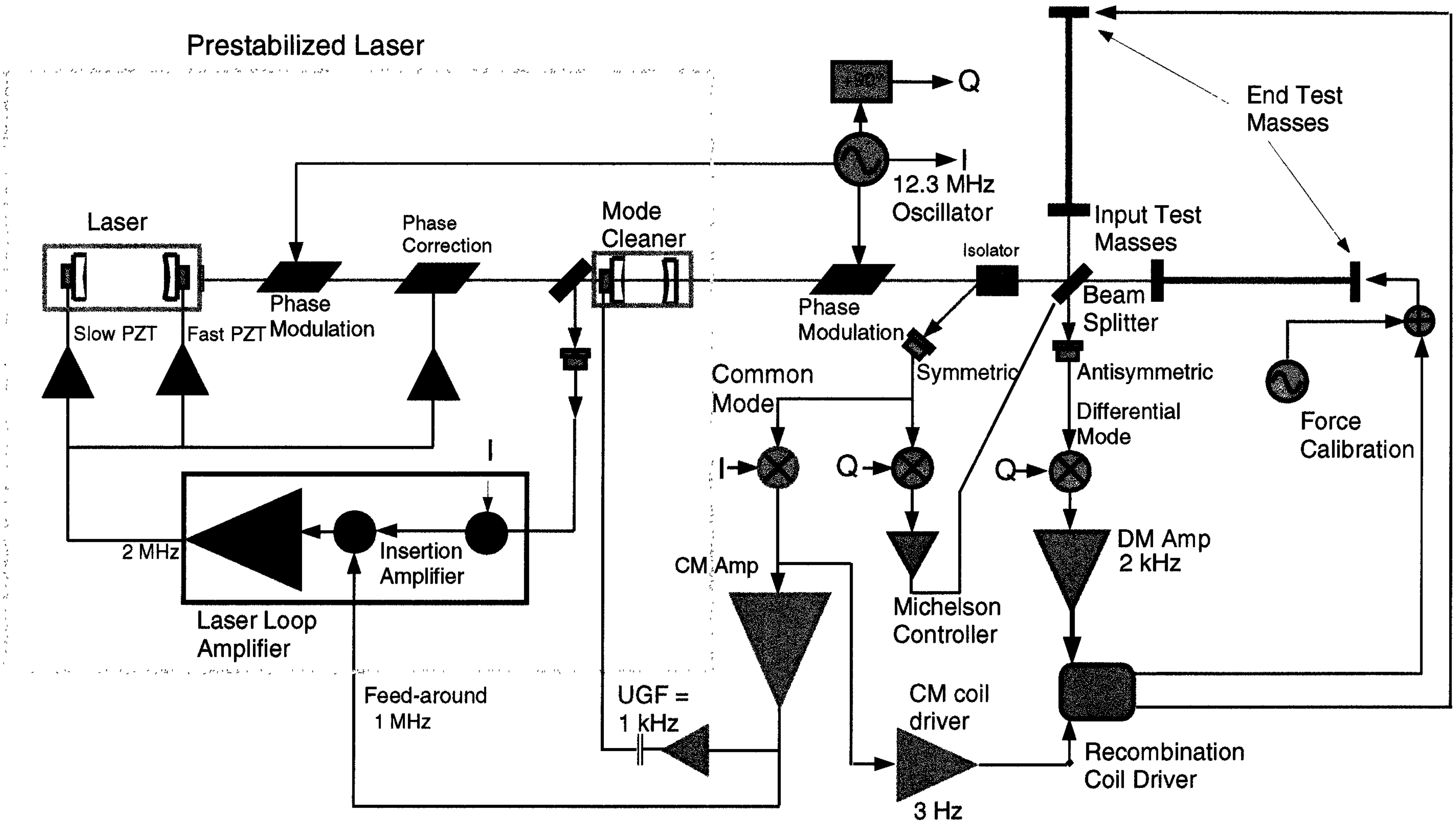
›› Full-up VME/Epics control of prestabilized laser

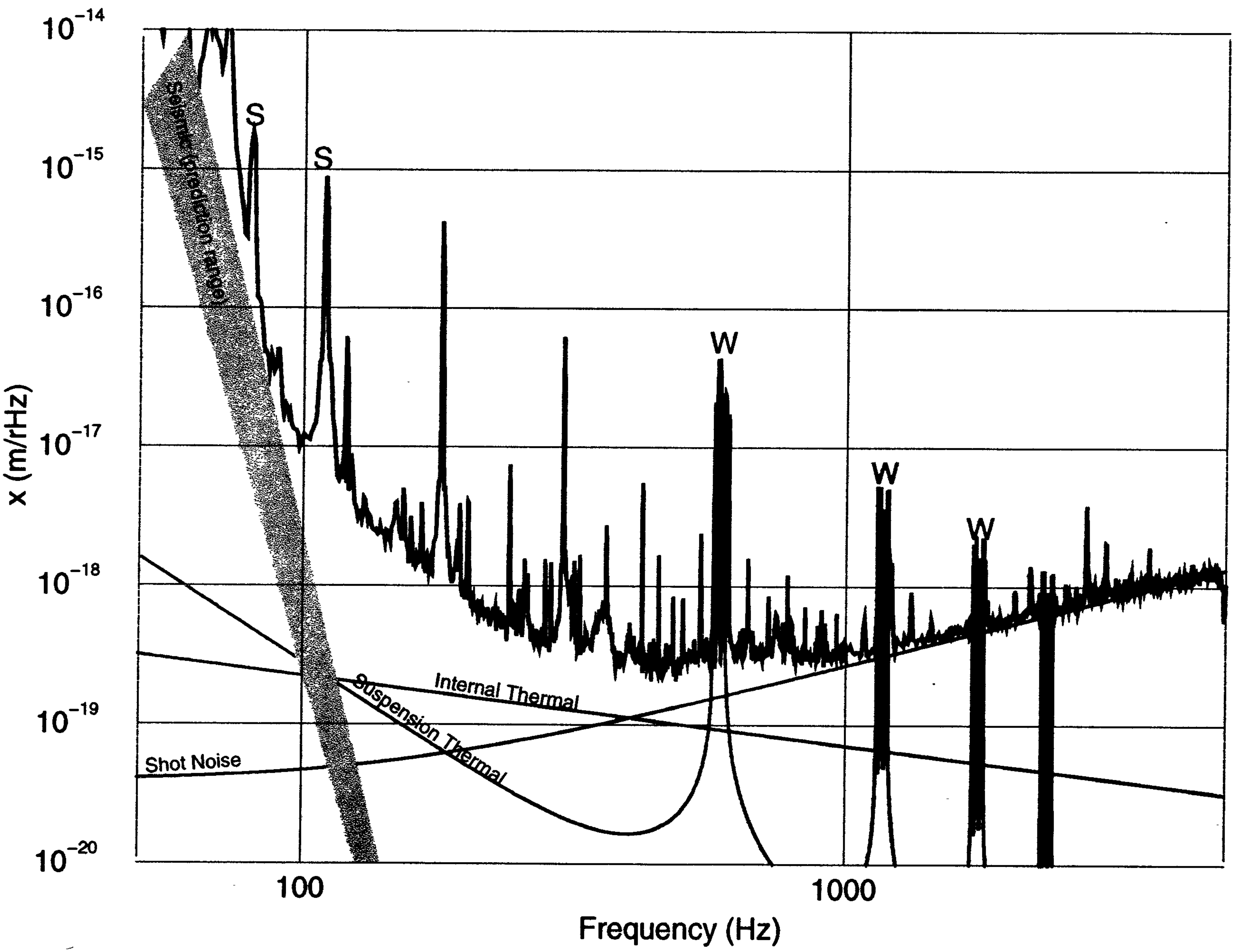
Recombined Interferometer



- Degrees of Freedom:
  - ››Common mode arm length = $L_1 + L_2$
  - ››Differential arm length (GW signal) = $L_1 - L_2$
  - ››Michelson near-mirror difference = $l_1 - l_2$

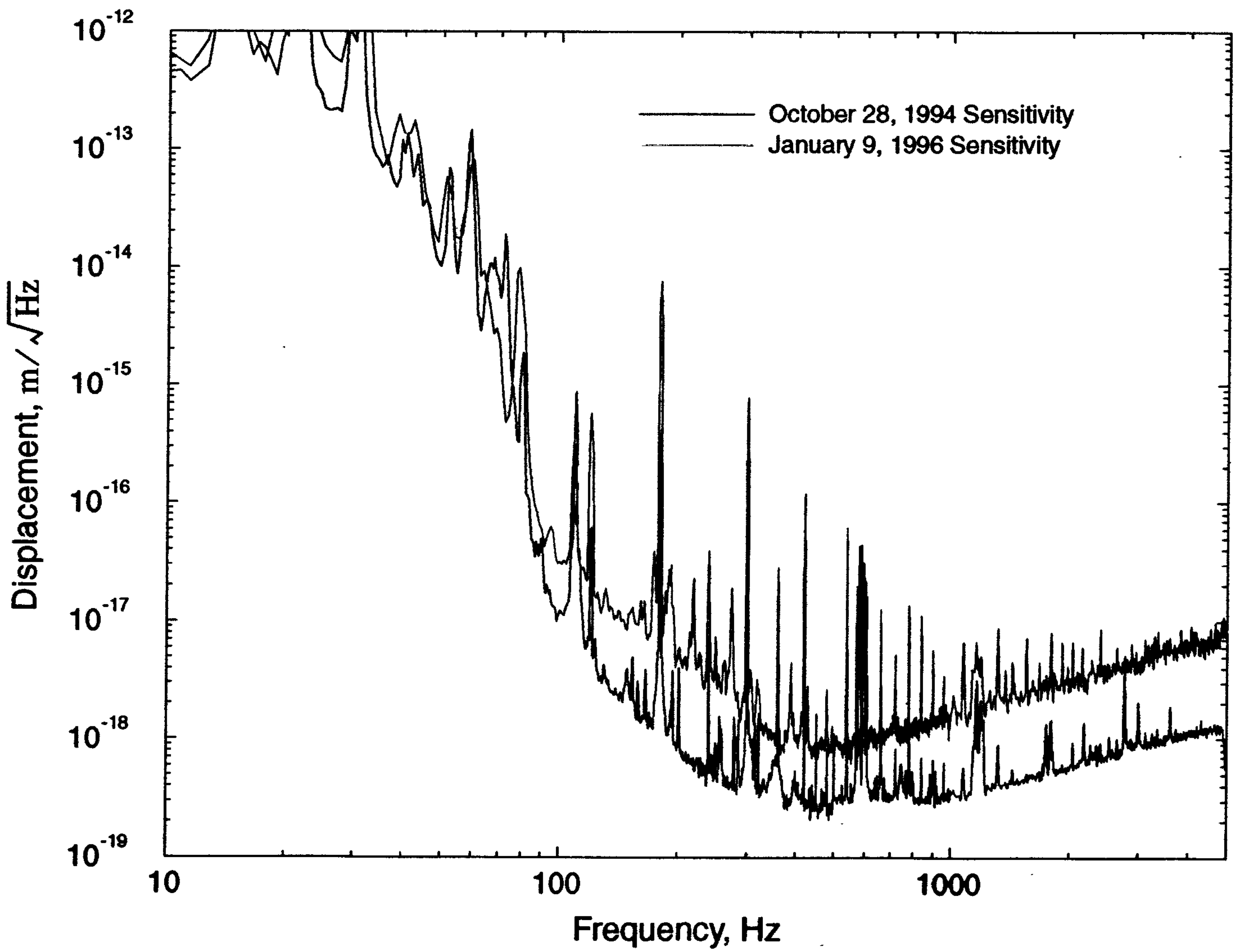
RECOMBINATION TOPOLOGY





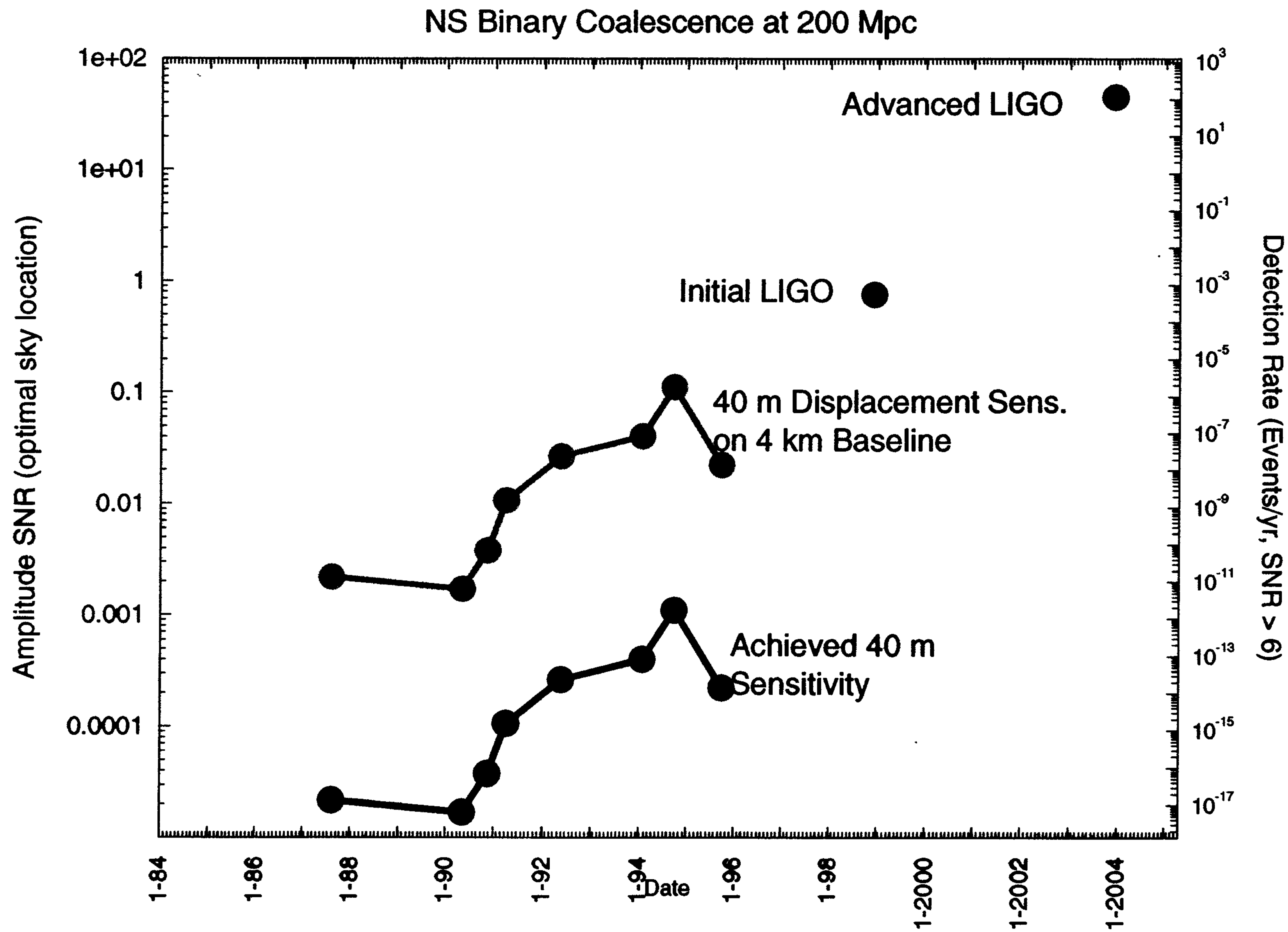
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
x (m/rHz)
S
S
W
W
W
W
Seismic (prediction range)
Internal Thermal
Suspension Thermal
Shot Noise
100
1000
Frequency (Hz)

Recombination Sensitivity Comparison



5 of 11

Detectabilityof NSBC with 40 m Interferometer



Lock Acquisition

- Largest concern before recombination
- Lock acquisition sequence:

  ››Beam splitter servo held antisymmetric port dark

  ››Common mode servo held one arm on resonance (typically the south arm)

  ››Differential mode would hold other arm on resonance after passing through resonance a number of times
- It was originally expected that the out of lock arm passing through resonance would disrupt the resonance of the arm in lock.
- In practice the common mode and beam splitter servos typically were not disrupted by movement of the out of lock arm.

Calculation vs. Measurement

- The closed loop interferometer response functions were measured at 132.5 Hz.
- Matrices in the analytic expression for the closed loop response were measured, except for *P*, which was taken from the calculated matrix of discriminants.
- Comparison of calculated (shaded) and measured (normal) interferometer response:

Loop Driven	Loop in which Response Measured					
	Common mode (1)		**Beam splitter (2)**		**Differential mode (3)**	
1	1.2	1.4	1.9×10^{-1}	1.6	1.9×10^{-2}	2.7×10^{2}
2	7.1×10^{-10}	0	5.7×10^{-5}	1.1×10^{-5}	2.6×10^{-5}	3.8×10^{-6}
3	1.9×10^{-6}	1.9×10^{-6}	2.8×10^{-3}	3.0×10^{-3}	1.0	1.0

Explanation of Discrepancies

- Order of magnitude difference between calculation and measurement when driving beam splitter likely due to:

  ››Beam splitter voltage to displacement calibration not as well known as for test masses

  ››Measurements were done near unity gain frequency of beam splitter

- Very large discrepancy in common mode to beam splitter and common mode to differential mode responses likely due to cross talk in common mode test inputs of the recombination coil driver.

  ››10^{-2} cross talk meant driving not only common mode, but differential mode as well.

  ››Measurements on first row were corrected by common mode loop gain factor (2.4×10^5 at 132 Hz).

  ››Small differential mode drive multiplied by loop gain factor could explain all of the erroneously large measured values to within 40%.

Frequency and Intensity Noise

- Common Mode (Frequency) Noise

  ››Injected monochromatic signals into common mode servo

  ››Made peak-to-valley measurements of both common mode and interferometer outputs

  ››Found common mode noise accounts for less than approximately $2\times10^{-19}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$ between 275 - 750 Hz

  ››Similar results with replacement laser system

- Intensity Noise

  ››Injected monochromatic and broadband intensity noise to increase noise at interferometer output

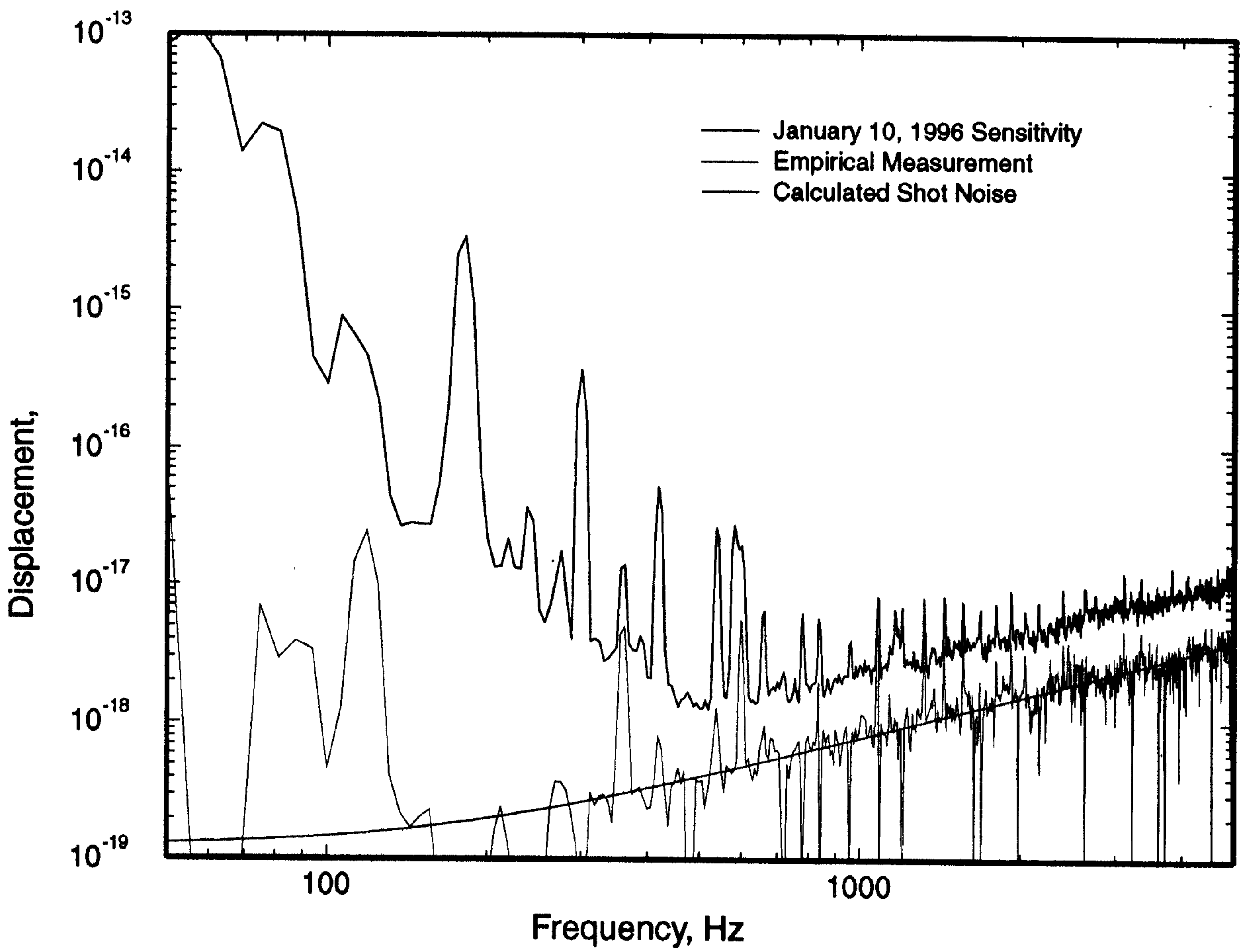
  ››Compared with residual intensity noise measured on independent photodiode (not part of intensity noise servo loop)

  ››Found intensity noise was less than $3\times10^{-19}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$ from 500 to 1000 Hz

  ››Replacement laser system intensity noise was approximately a factor of 6 worse and limited the interferometer output above 500 Hz

Shot Noise Estimate

- With no laser light, calibrated interferometer output (accounting for servo loop gain) from incandescent light source of same power as incident during normal operation



LIGO-G960000-00-M