Some Effects of Earthquakes, Temperature, Wind Storms and Barometric Pressure on the Interferometer at Hanford

Robert Schofield

Masahiro Ito
Rauha Rahkola
Evan Mauceli
Ray Frey
David Strom
Jim Brau

University of Oregon

Some Concerns With Low Frequency Influences

- Loss of lock
- Need for increased servo loop gain
- May eat up actuator range
- Possible increased background in the LIGO frequency band
- Possible modulation of noise in the LIGO band

Guralp Seismometer and Applied Geomechanics Tilt Meter

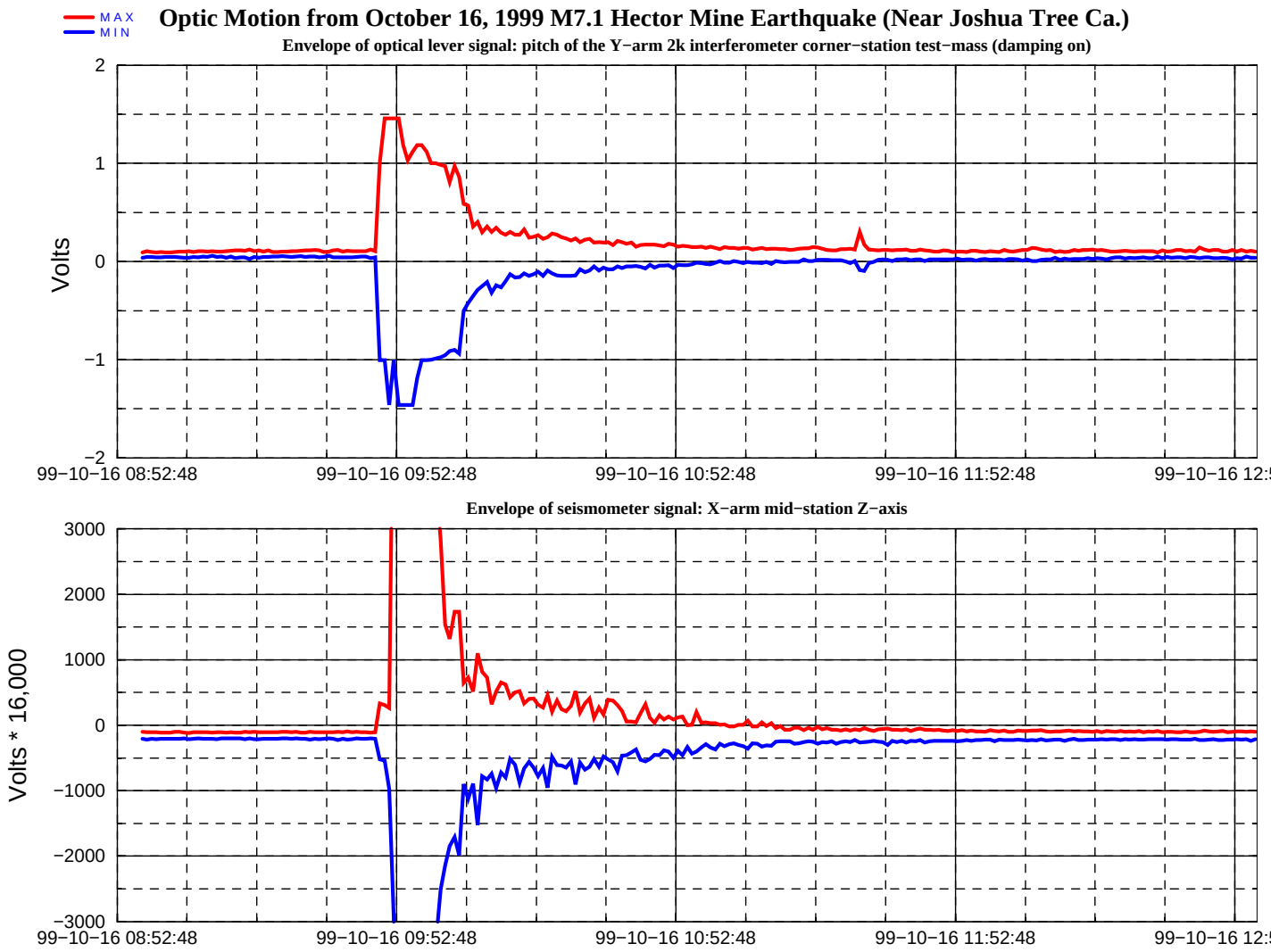
Optical Lever Pier and Vacuum Chamber for X-arm 2k Input Test Mass

The test mass, 2k ITMX, is 33m away in the BSC just visible in the background.

Calibration Factors, March 14, 2000

Signal	Calculation	Calibration Factor	Error*
Seismometers	((1 m/s) / 800 V) * (4 V / 65536 counts)	0.076 μm/s per count	17%
Tilt meters	(100 μR/V) * (4 V / 65536 counts)	0.0061 μR per count	16%
Shadow sensors	($1x10^{-3}$ m / 1.5 V) * (4 V / 65536 counts)	0.041 μm per count	40%
Optical levers on input test masses	($1x10^{-3}$ m/ 1.75 V) / 66.6 m	17 μR per volt (EPICS channel)	40%
Optical levers on end test masses	($1x10^{-3}$ m/ 1.75 V) / 12.2 m	46.8 μR per volt (EPICS channel)	40%
Control Signal	direct calibration	0.00118 μm per count	4%

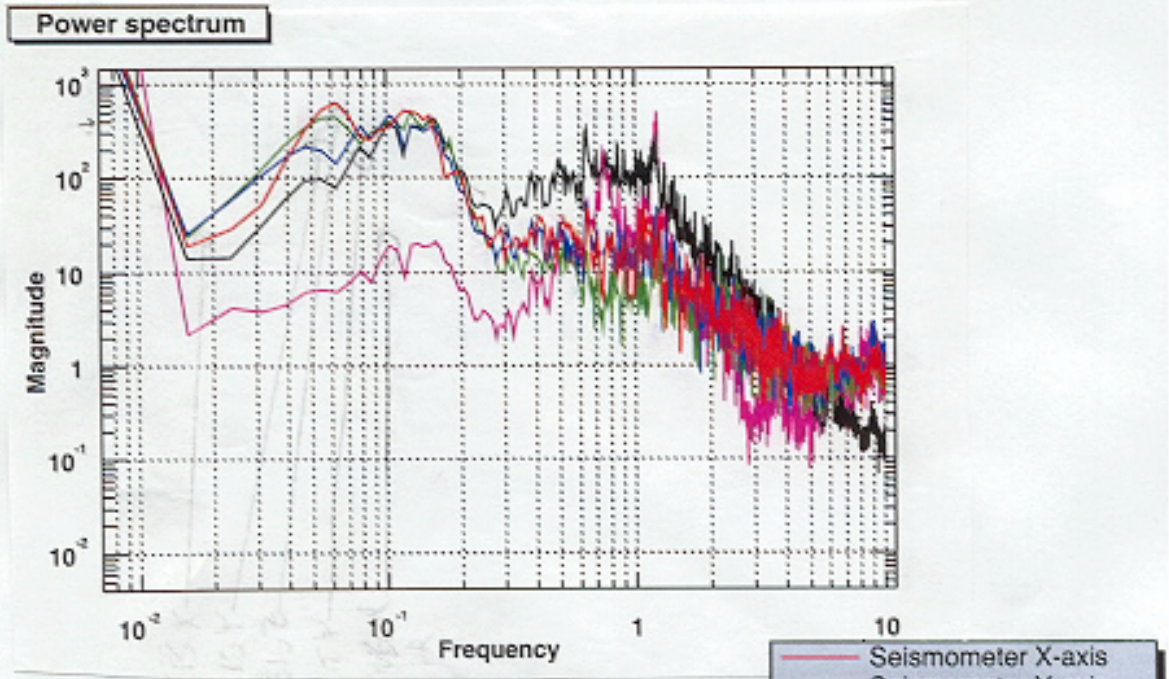
* 15% uncertainty range for adc's (variation obtained from a couple of actual calibrations) + maximum variation of instrument calibration (e.g. the most extreme factory calibration for an individual seismometer axis is 816 giving 2% for a total uncertainty of 17%) - Robert


MAX
MIN
Optic Motion from October 16, 1999 M7.1 Hector Mine Earthquake (Near Joshua Tree Ca.)
Envelope of optical lever signal: pitch of the Y−arm 2k interferometer corner−station test−mass (damping on)
Volts
2
1
0
−1
−2
99−10−16 08:52:48
99−10−16 09:52:48
99−10−16 10:52:48
99−10−16 11:52:48
Envelope of seismometer signal: X−arm mid−station Z−axis
Volts * 16,000
3000
2000
1000
0
−1000
−2000
−3000

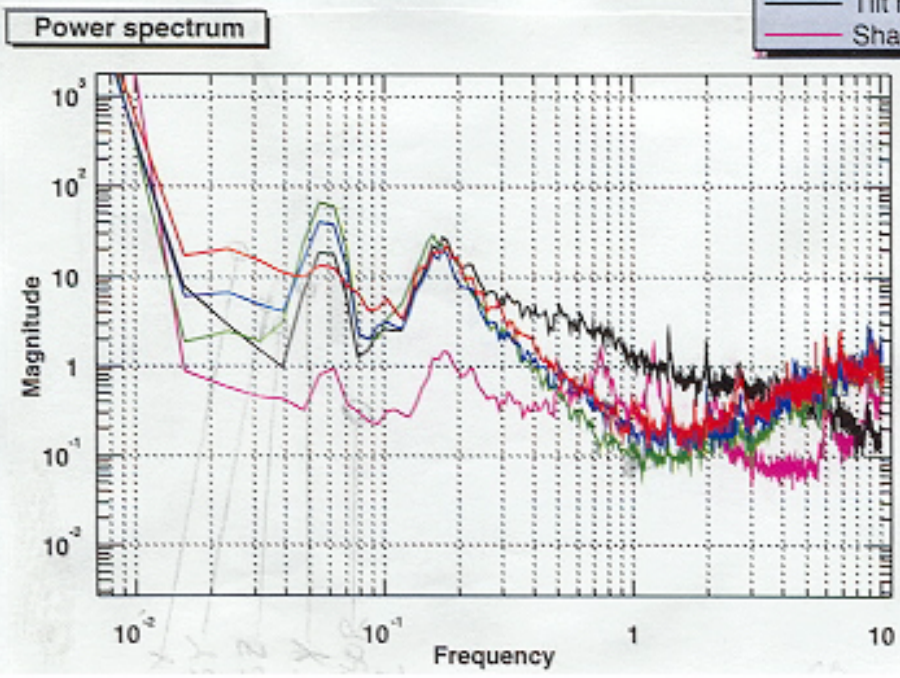
Two Earthquakes Registered by Seismometers, Tilt Meters and Shadow Sensors

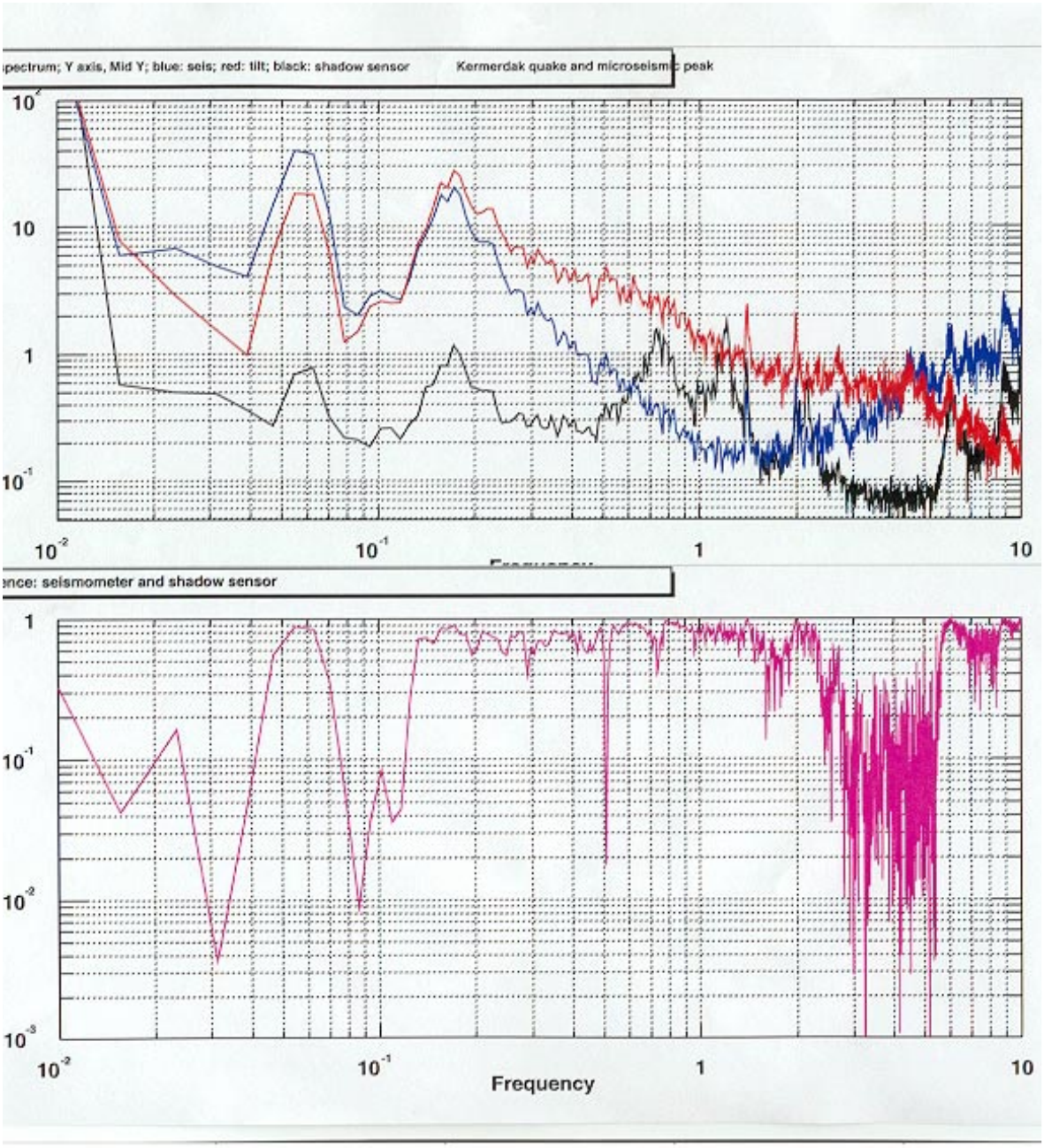
All signals from mid-Y station

M 5.1, 155 miles off Oregon coast, Jan. 20, 2000



M 5.5, near Kermadic islands, Jan. 20, 2000




pectrum; Y axis, Mid Y; blue: seis; red: tilt; black: shadow sensor
Kermerdak quake and microseism peak
10
1
10^-1
10^-2
10^-1
1
10
nce: seismometer and shadow sensor
1
10^-1
10^-2
10^-3
10^-2
10^-1
1
10
Frequency

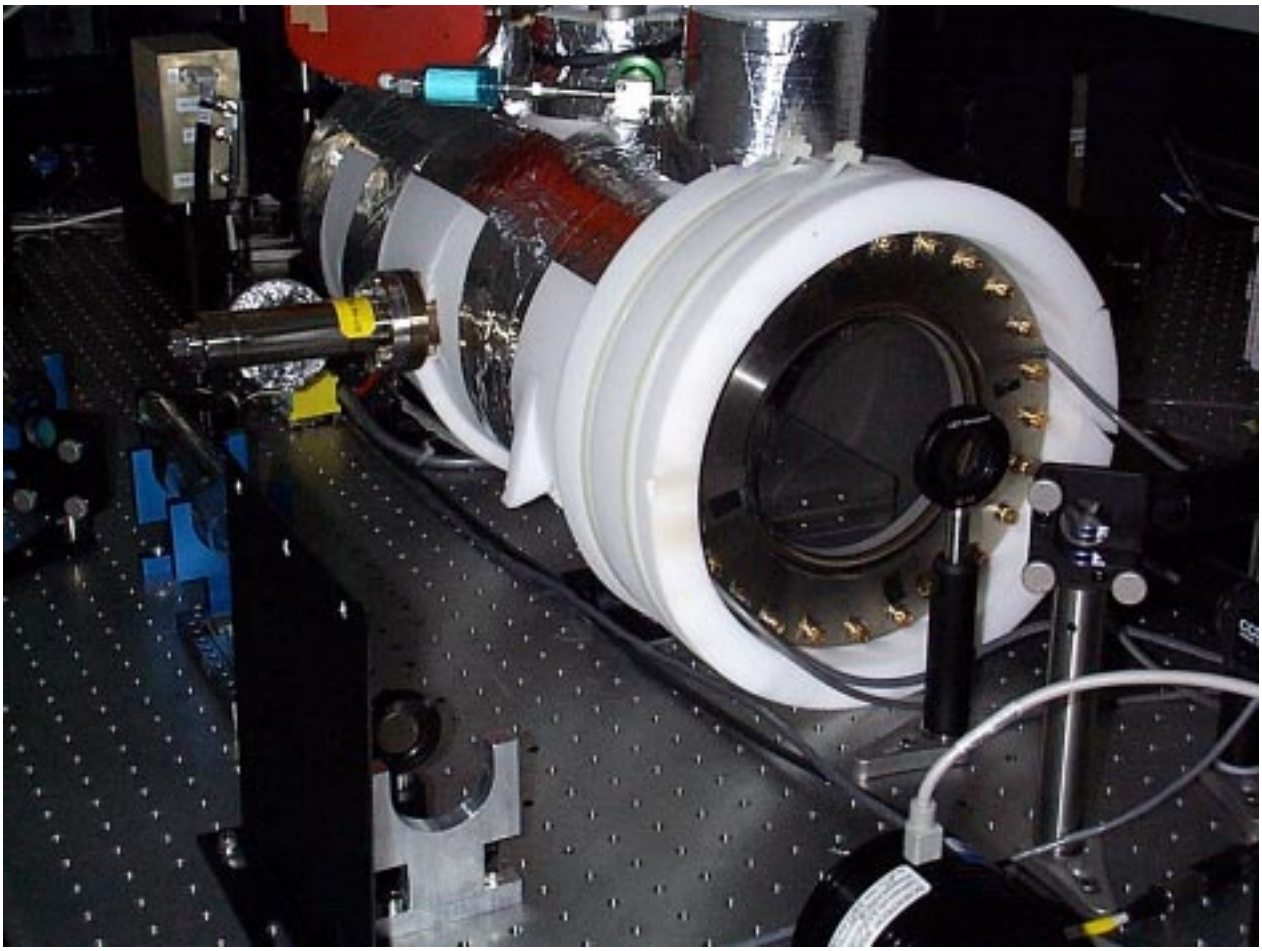
Rough Agreement of Tilt Meter, Seismometer and Shadow Sensor

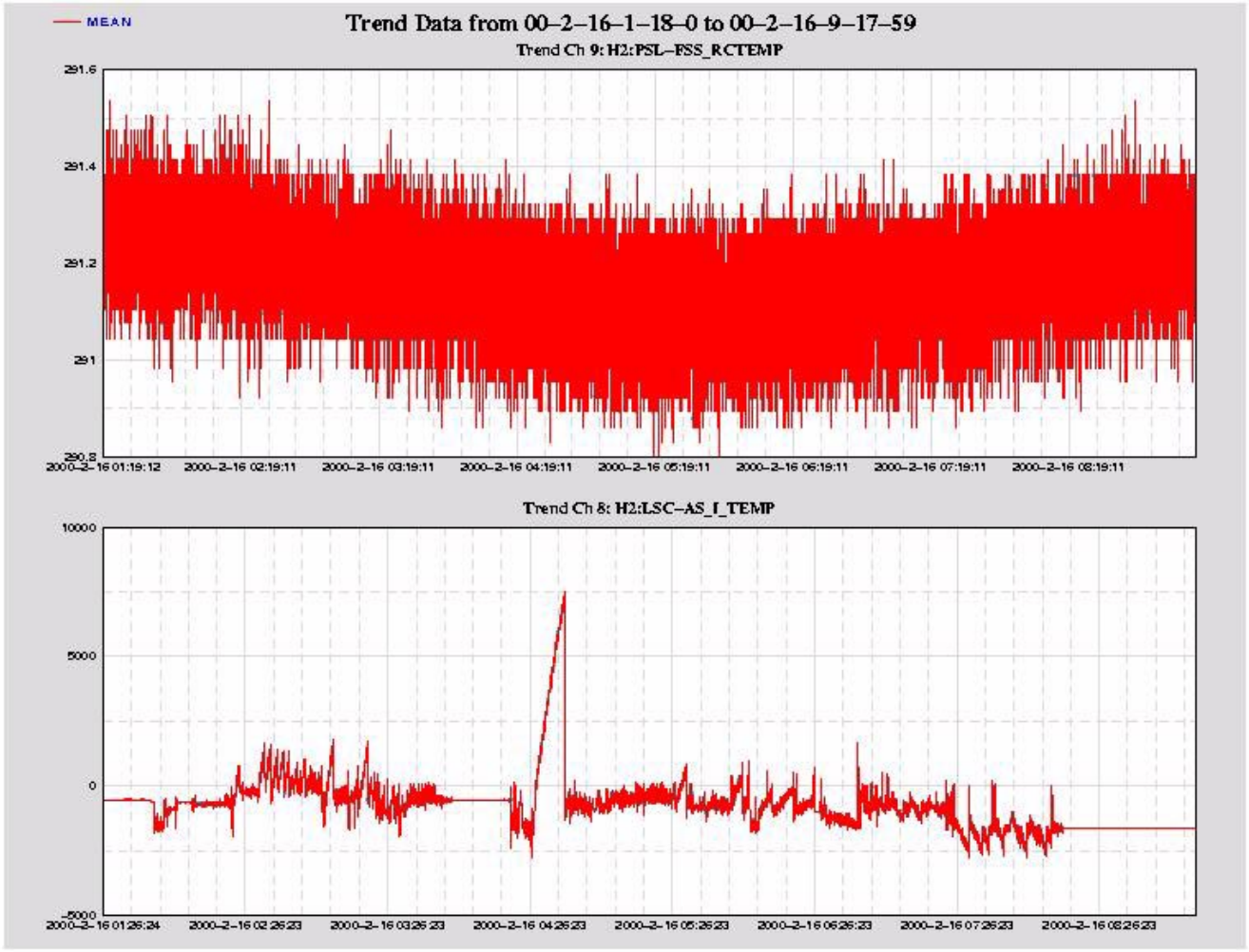
Approximate Amplitude of Motion of the Optic Relative to the Optic Support Structure

Event	Peak f	From Tilt meter*	From Seismometer*	From Shadow sensor
1/20/00 Oregon coast quake	0.1 Hz	2.5 μm	2.6 μm	3.2 μm
1/20/00 Kermadic islands	0.5 Hz	0.031 μm	0.025 μm	0.020 μm
1/20/00 microseismic peak	0.16 Hz	0.15 μm	0.15 μm	0.076 μm

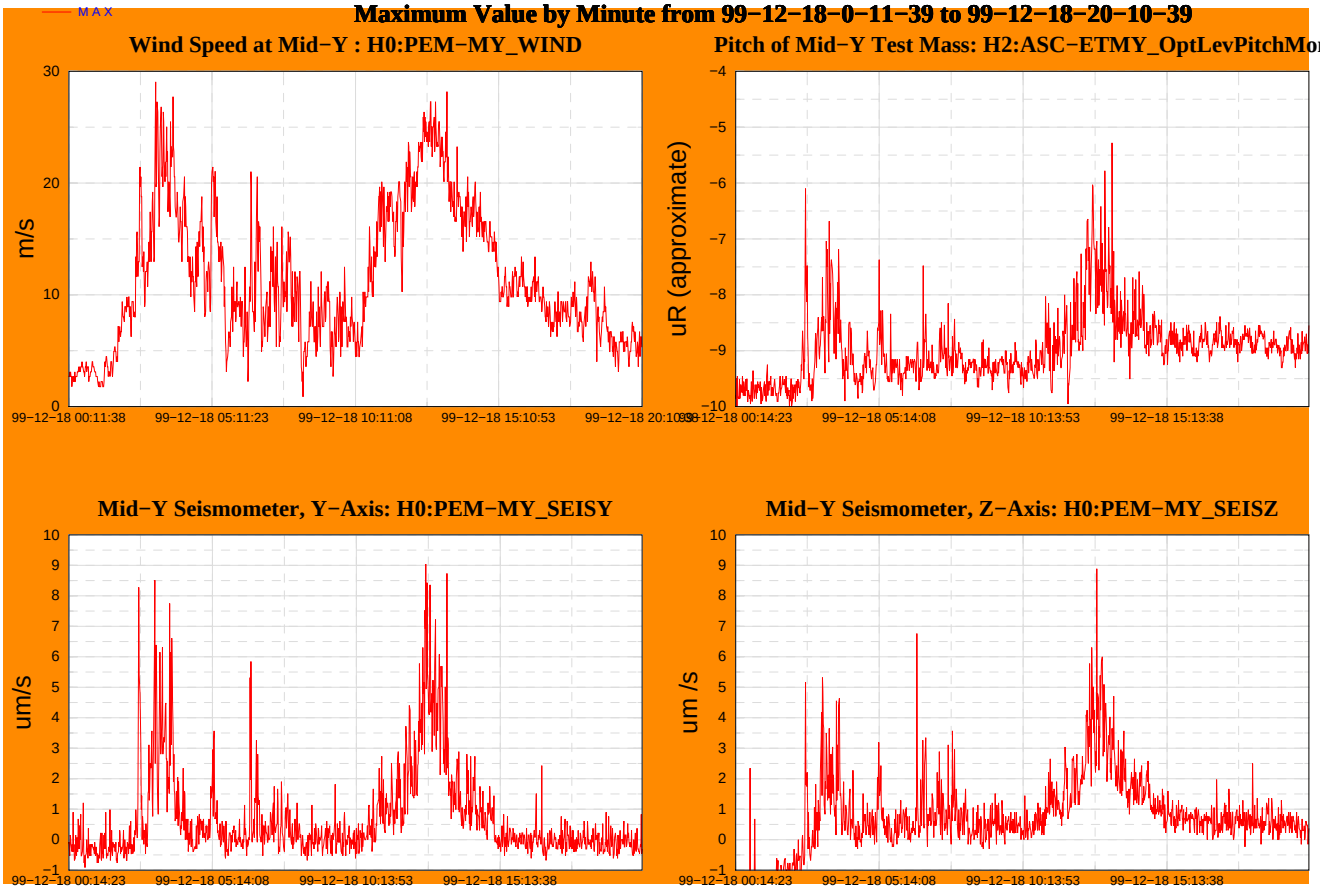
* The tilt meter was assumed to measure acceleration; accelerations calculated from the tilt meter and seismometer signals were assumed to be balanced by g sin(θ) (DC approximation); the displacement of the optic from the support structure was calculated from this angle (the length of the pendulum was assumed to be 0.5 m).

Reference Cavity

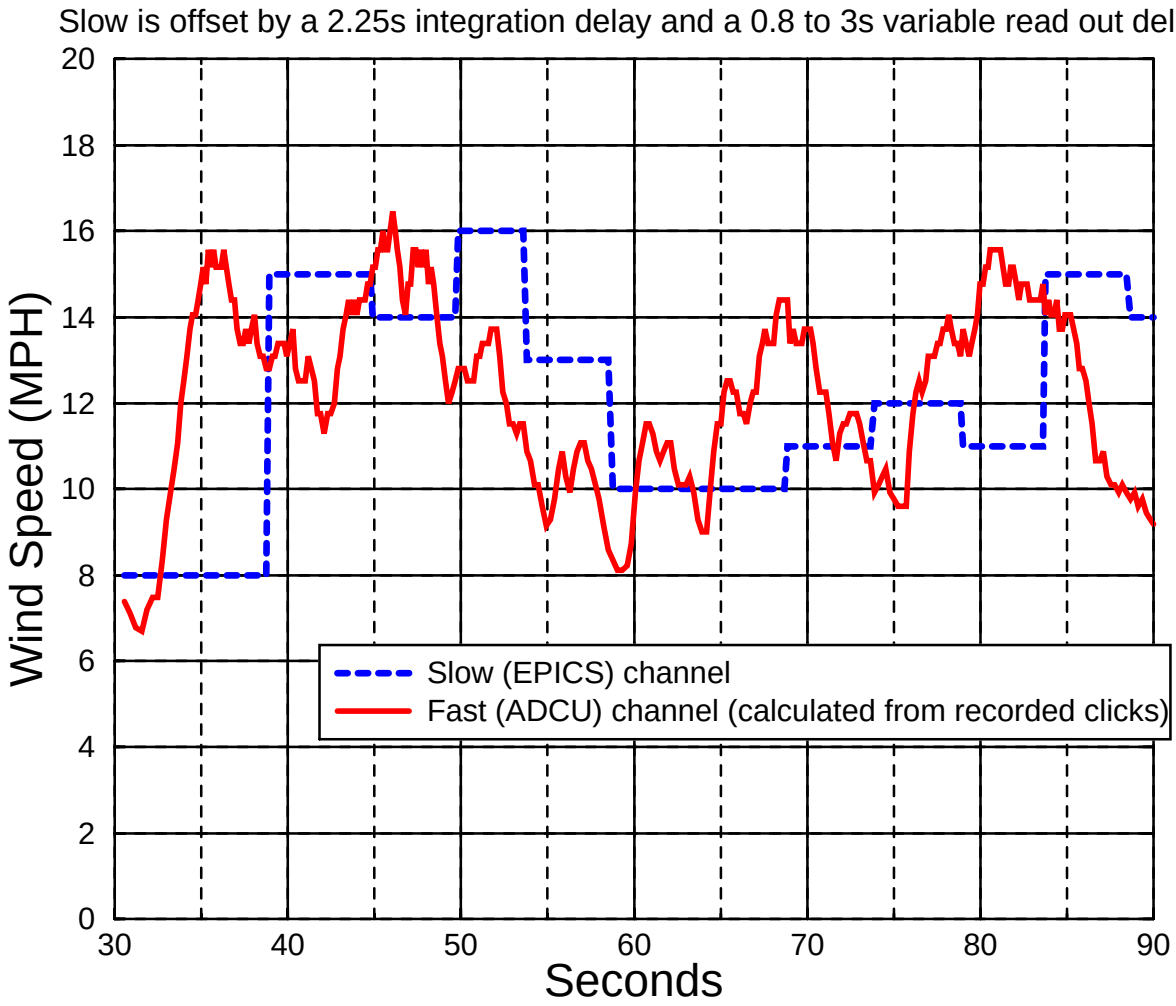



MEAN
Trend Data from 00–2–16–1–18–0 to 00–2–16–9–17–59
Trend Ch 9: H2:PSL–FSS_RCTEMP
291.6
291.4
291.2
291
290.8
2000–2–16 01:19:12
2000–2–16 02:19:11
2000–2–16 03:19:11
2000–2–16 04:19:11
2000–2–16 05:19:11
2000–2–16 06:19:11
2000–2–16 07:19:11
2000–2–16 08:19:11
Trend Ch 8: H2:LSC–AS_I_TEMP
10000
5000
0
–5000
2000–2–16 01:26:24
2000–2–16 02:26:23
2000–2–16 03:26:23
2000–2–16 04:26:23
2000–2–16 05:26:23
2000–2–16 06:26:23
2000–2–16 07:26:23
2000–2–16 08:26:23

X-end Davis Weather Station

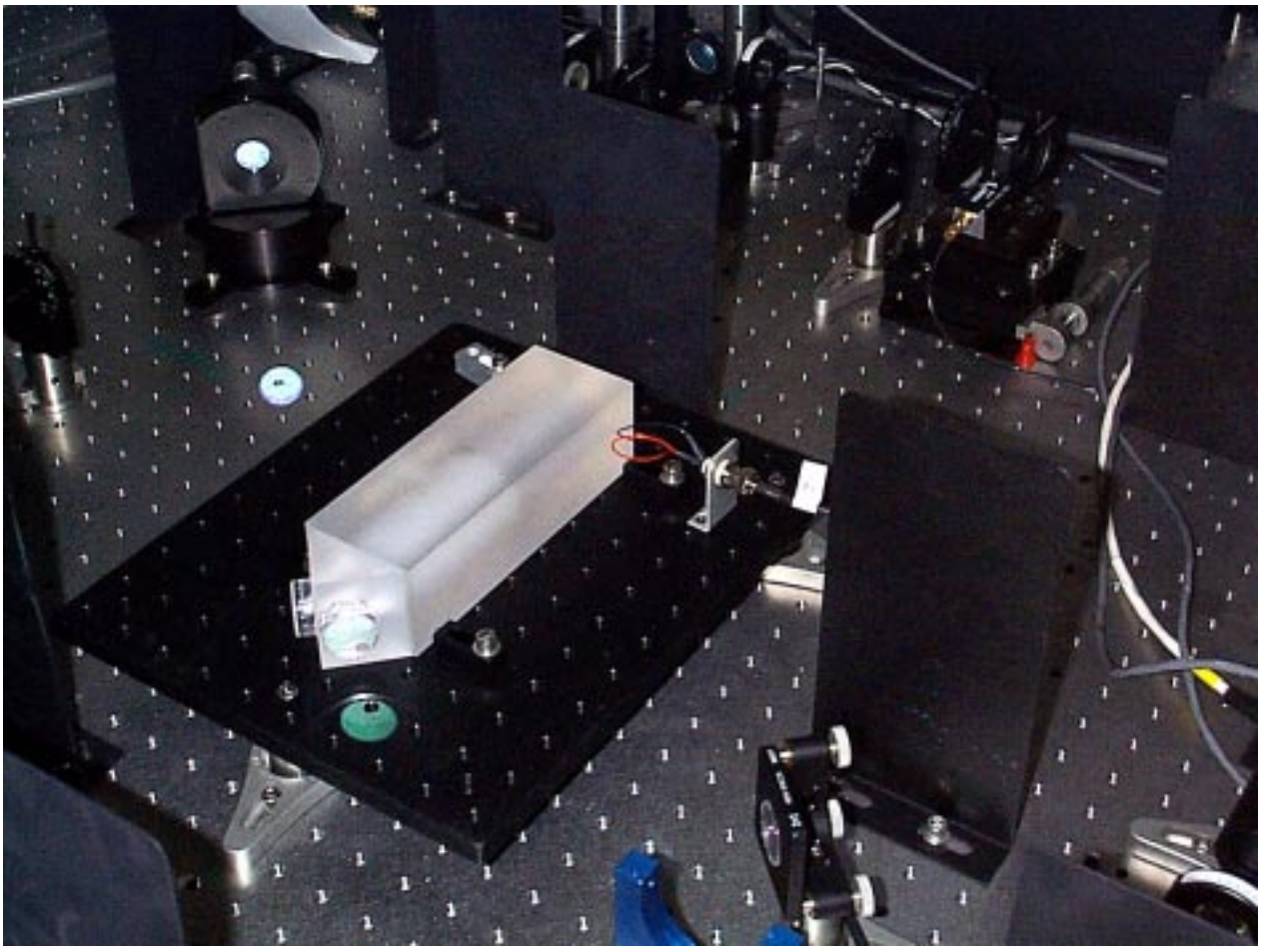

MAX
Maximum Value by Minute from 99-12-18-0-11-39 to 99-12-18-20-10-39
Wind Speed at Mid-Y : H0:PEM-MY_WIND
m/s
30
20
10
0
99-12-18 00:11:38
99-12-18 05:11:23
99-12-18 10:11:08
99-12-18 15:10:53
99-12-18 20:10:39
Pitch of Mid-Y Test Mass: H2:ASC-ETMY_OptLevPitchMor
uR (approximate)
-4
-5
-6
-7
-8
-9
-10
99-12-18 00:14:23
99-12-18 05:14:08
99-12-18 10:13:53
99-12-18 15:13:38
Mid-Y Seismometer, Y-Axis: H0:PEM-MY_SEISY
um/s
10
9
8
7
6
5
4
3
2
1
0
-1
99-12-18 00:14:23
99-12-18 05:14:08
99-12-18 10:13:53
99-12-18 15:13:38
Mid-Y Seismometer, Z-Axis: H0:PEM-MY_SEISZ
um /s
10
9
8
7
6
5
4
3
2
1
0
-1
99-12-18 00:14:23
99-12-18 05:14:08
99-12-18 10:13:53
99-12-18 15:13:38

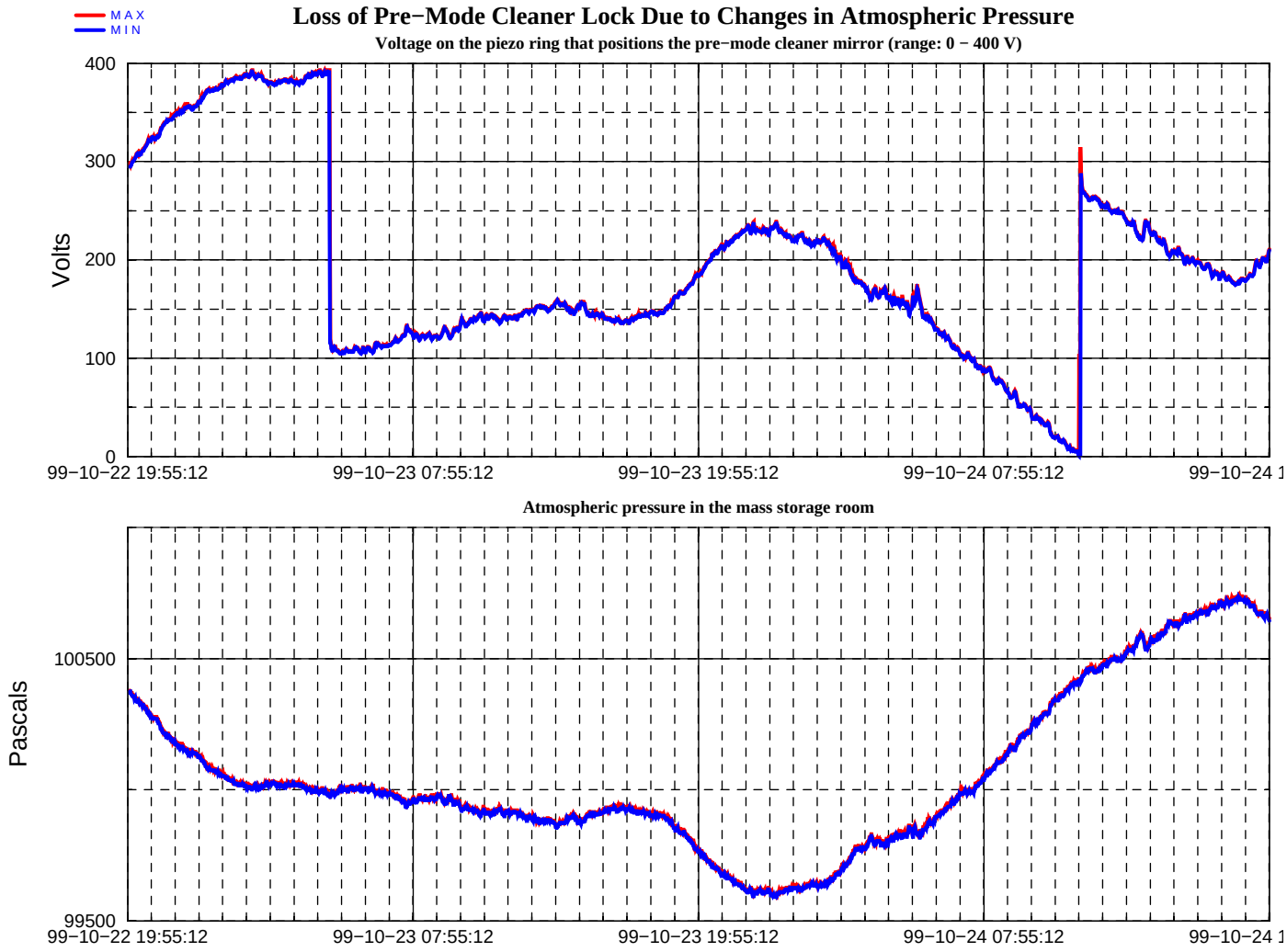
Anemometer data − fast and slow channels



Pre-Mode Cleaner

Piezo length control is on far side; cavity is open to atmosphere.




MAX
MIN
Loss of Pre−Mode Cleaner Lock Due to Changes in Atmospheric Pressure
Voltage on the piezo ring that positions the pre−mode cleaner mirror (range: 0 − 400 V)
Volts
400
300
200
100
0
99−10−22 19:55:12
99−10−23 07:55:12
99−10−23 19:55:12
99−10−24 07:55:12
Atmospheric pressure in the mass storage room
Pascals
100500
99500
99−10−22 19:55:12
99−10−23 07:55:12
99−10−23 19:55:12
99−10−24 07:55:12

PMC - Piezo Range Needed to Hold Lock For Historical Barometric Pressure Fluctuations at Hanford

Index of refraction changes with barometric pressure cause a strain in optical path length of about 2.7×10^{-9} per Pascal. The optical path length of the pre-mode cleaner is about 0.4 m.

Time Span	Maximum Pressure (Pascals)	Minimum Pressure (Pascals)	Minimum Piezo Range (μm)
1998 - 1999	102,122	96,806	2.7
1955 - 1999	103,442	95,993	3.8

In order to acquire lock at any pressure, an extra free spectral range (0.5 μm) is needed. Also, when lock is acquired, the piezo setting must be coordinated with pressure, or else the range must be further increased.

Piezo range > 4.3 μm (a factor of 6.4 over present range of 0.67μm) or air-tight PMC.

Summary

Earthquakes are swinging optics 1 μR or more with some regularity (statistics to be determined). On at least 4 occasions in the last 5 months, motion has been greater than 50 μR.

Building temperature fluctuations have shown up in control and optical lever signals.

During a 25 m/s wind storm we observed test mass angular motion of up to about 4 μR. Gust meters are needed.

The piezo range of the PMC must be increased by a factor of about 6 to maintain lock for pressure fluctuations of historical magnitude.

Environmental channels are coming on line and we are beginning to use them to characterize the interferometer.