LIGO

Commissioning of the LIGO Detector

Rick Savage

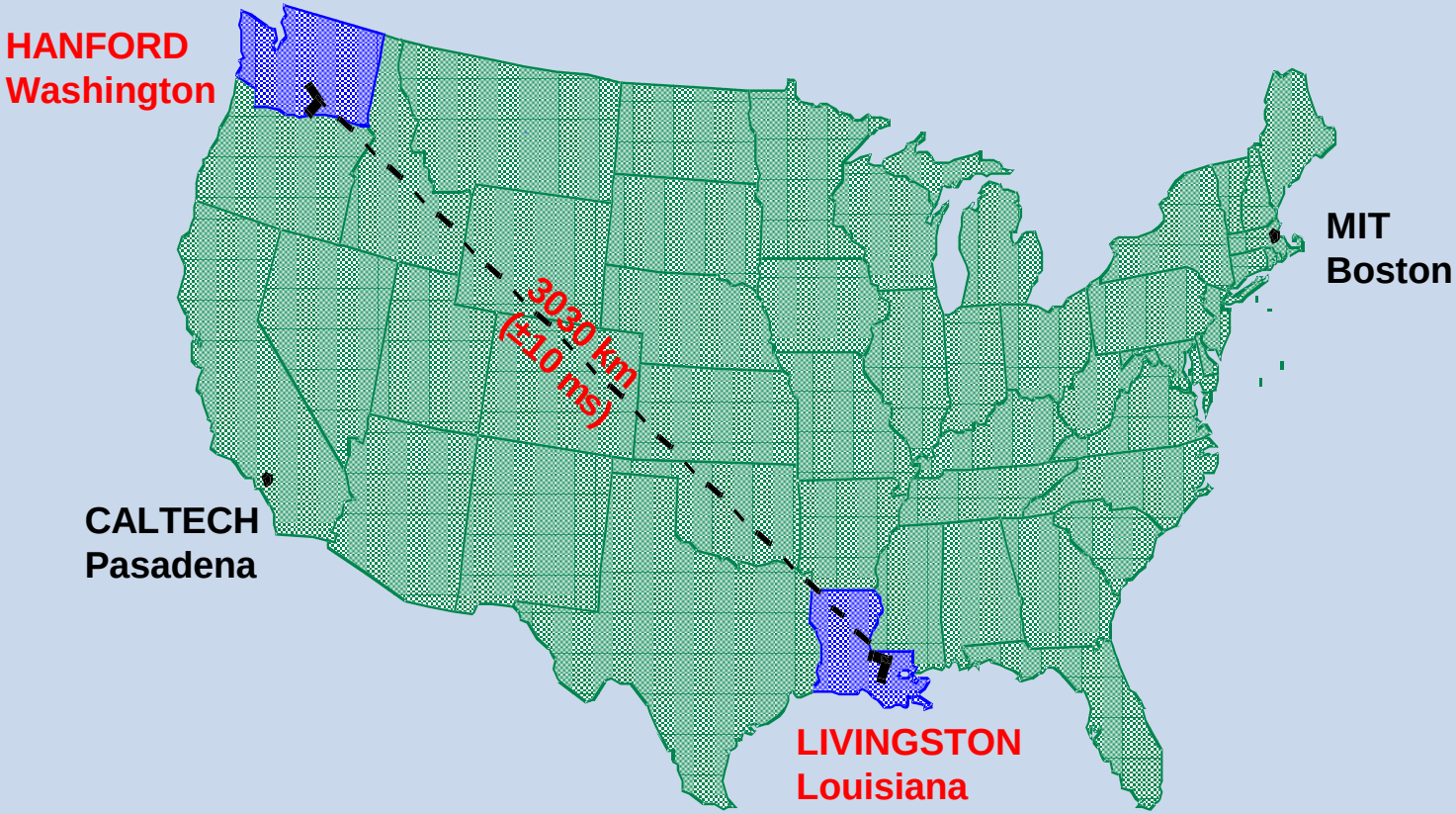
LIGO Hanford Observatory

University of Tokyo

July 12, 2002

LIGO

LIGO Observatories



LIGO

Hanford Observatory (LLO)

Livingston Observatory (LLO)

LIGO Hanford Observatory Commissioning Players

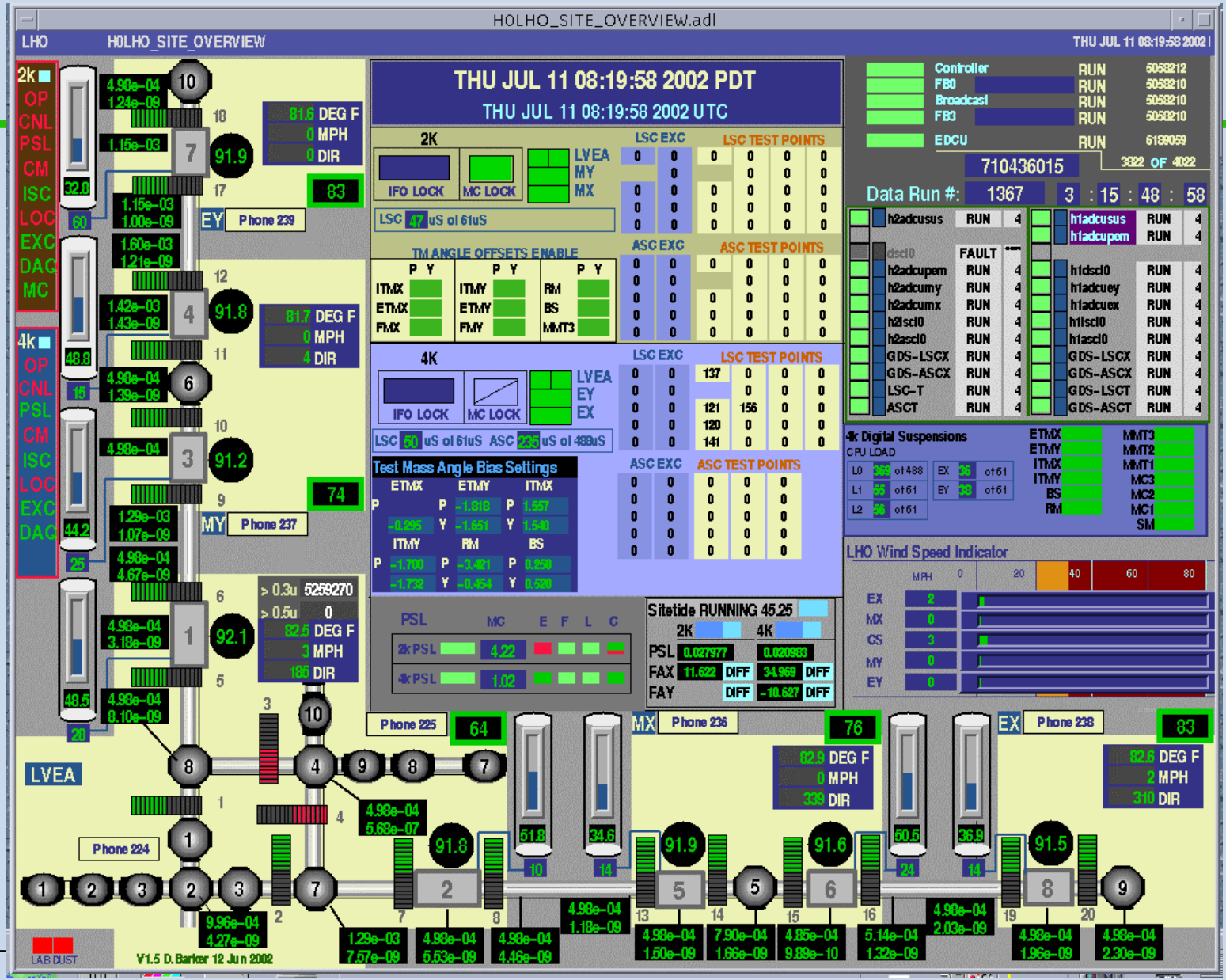
- Scientists Resident at LHO
  - Dick Gustafson – UM
  - Michael Landry – postdoc
  - Fred Raab – Head LHO
  - Rick Savage
  - Paul Schwinberg
  - Daniel Sigg
- Visiting Scientists
  - Stan Whitcomb – CIT
  - Robert Schofield – UO
  - Nergis Mavalvala – MIT
  - Peter Fritschel – MIT
  - Rana Adhikari – MIT (grad student)
  - Bill Kells – CIT
  - Luca Matone - CIT
- Grad Students
  - Bill Butler – Rochester
  - Masahiro Ito – UO
  - Rana Rakhola – UO
- Operators
  - Betsy Bland
  - Corey Gray
  - Mark Guenther
  - Nathan Hindman
  - Mark Lubinski
  - Gerardo Moreno
  - Hugh Radkins
  - Cheryl Vorvick
- Support Staff
  - Dave Barker – CDS
  - Greg Mendell – LDAS
  - Richard McCarthy – Elect.
  - Josh Myers – Elect.
  - Doug Cook – Optics
  - Kyle Ryan – Vac.
  - John Worden – Vac.
  - Bartie Rivera –Vac. prep.
  - Christine Patton – Sys. Admin.
  - Otto Matherny – Business
  - Jill Berry – Admin.

LHO Daily Schedule

- Operators on site seven days per week.
  - » Two shifts per day
    - – 7:00 AM to 5:00 PM
    - – 4:00 PM to 2:00 AM
  - » Two operators per shift
- Electronics troubleshooting, cabling, system maint., etc. typically in the mornings.
- Begin operation of interferometers at about 2:00 PM daily.
- Electronic log book (elog) for all detector-related activities.
  - » Available on the web

  http://blue.ligo-wa.caltech.edu/ilog/
- Some increased seismic noise due to construction of new building
  - » Typically 6:30 AM to 3:30 PM
- High winds (> 25 mph) usually make full lock difficult, if not impossible.

LIGO Remote-controlled Interferometer



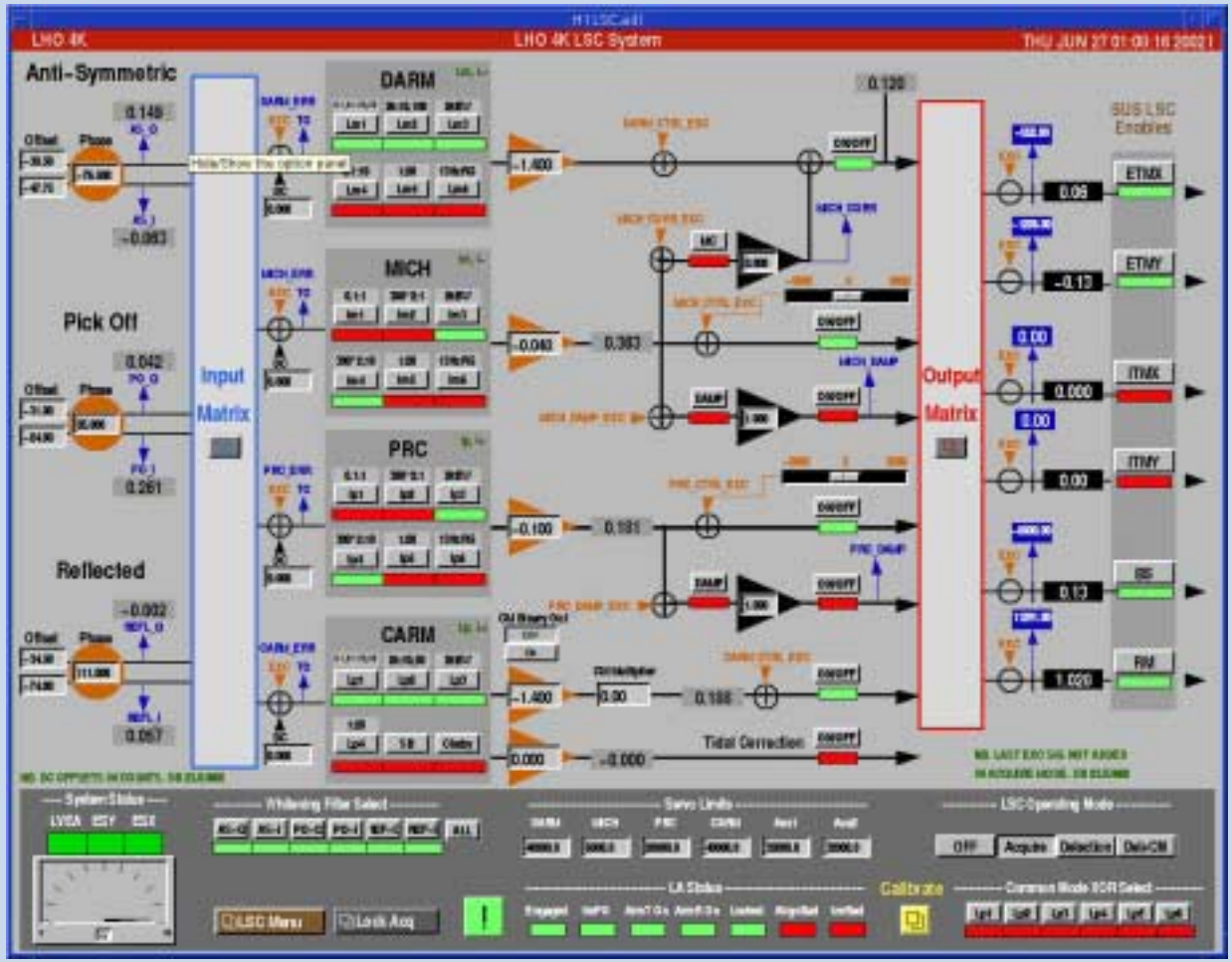
Hanford Control Room

Epics Control System

-All control via computer

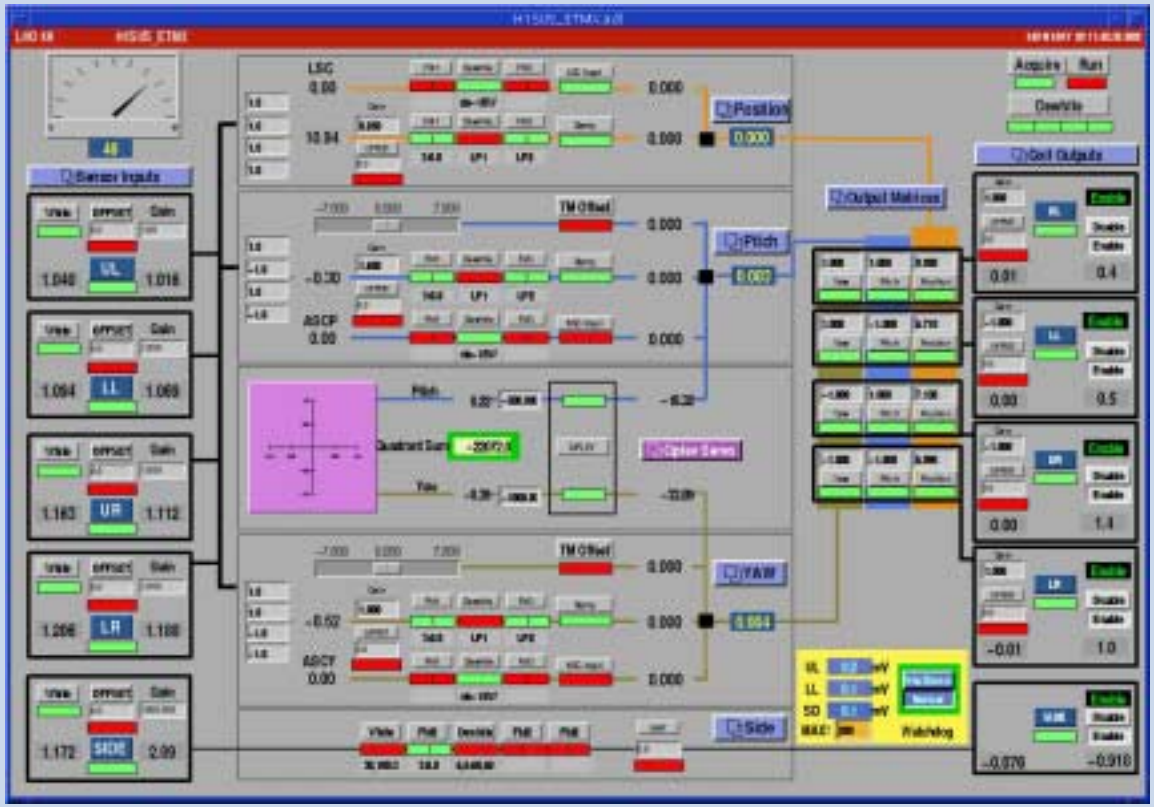
-Digital length and alignment control

-Dynamic control of input matrix in acquisition mode
(ala M. Evans)



4k Digital Suspension Control Screen

- Lots of digital filter stages
  - » Whitening and dewhitening
  - » Resonant gain stages
  - » Notches
  - » Combs
  - » Etc.
- Improved optical lever performance



LIGO Control and Data System (D. Barker at LHO)

- 12,770 “slow” EPICS channels per interferometer (LHO 4k ifo. with digital suspension controllers)
- 425 “fast” channels per ifo. (256 Hz, 2 kHz, 16 kHz)
- 60 16-kHz channels per ifo.
- 16 CDS computers (IOCs) per ifo.
- 3 MB/sec per ifo. written to frames
- 15 TB of full-frame storage capacity at LHO
- --> Previous 390 hrs. or 16.25 days of data available on disk
- Past 25 days of second-trend data available on disk
- All past minute-trend data available on disk

Automation of Interferometer Configuration Changes

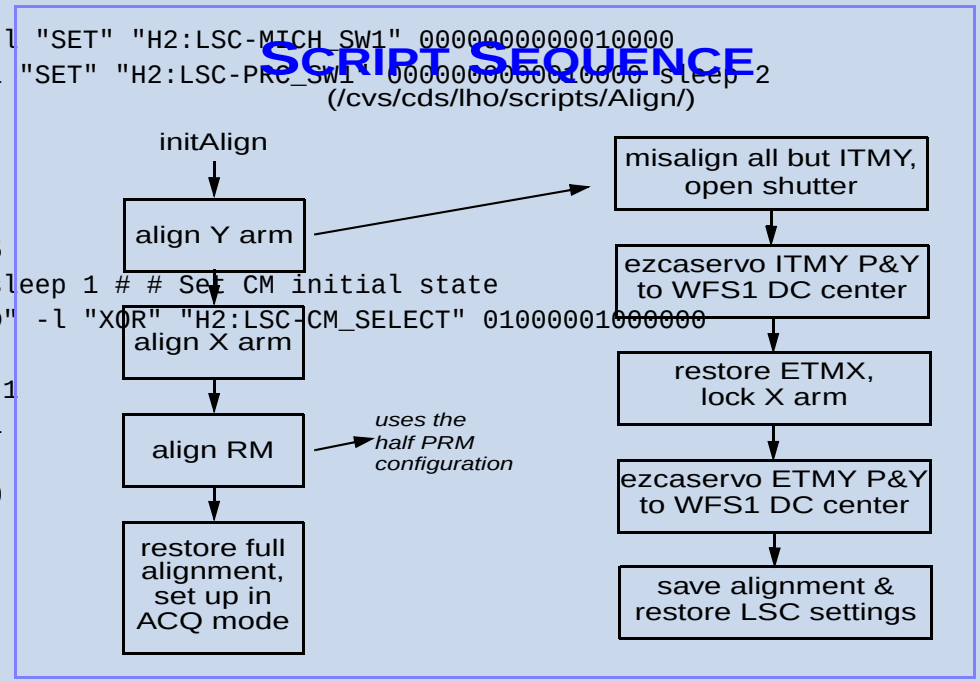
Common mode transition script

(D. Sigg)

```
# Turn MICH and PRC boost on
excawrite -b -r "H2:LSC-MICH_SW1R" -l "SET" "H2:LSC-MICH_SW1" 0000000000010000
ezcawrite -b -r "H2:LSC-PRC_SW1R" -l "SET" "H2:LSC-PRC_SW1" 0000000000010000 sleep 2
#
# Turn servo gains to final values
ezcawrite "H2:LSC-DARM_ERR_K" -1.2
ezcawrite "H2:LSC-CARM_ERR_K" -1.0
ezcawrite "H2:LSC-MICH_ERR_K" -0.085
ezcawrite "H2:LSC-PRC_ERR_K" -0.15 sleep 1 # # Set CM initial state
ezcawrite -b -r "H2:LSC-CM_SELECT_RD" -l "XOR" "H2:LSC-CM_SELECT" 0100000100000
ezcawrite H2:LSC-CM_OVERRIDE 0
ezcawrite H2:LSC-ComMode_CommGainIn 1
ezcawrite H2:LSC-ComMode_AOGainIn 11
ezcawrite H2:LSC-ComMode_ALGainIn 3
ezcawrite H2:IOO-MC_ERR_EXC_ENABLE 0
ezcawrite H2:IOO-MC3_LSC_IN 1
ezcawrite H2:LSC-ComMode_OpenLoop 1
#
```

Automated initial alignment

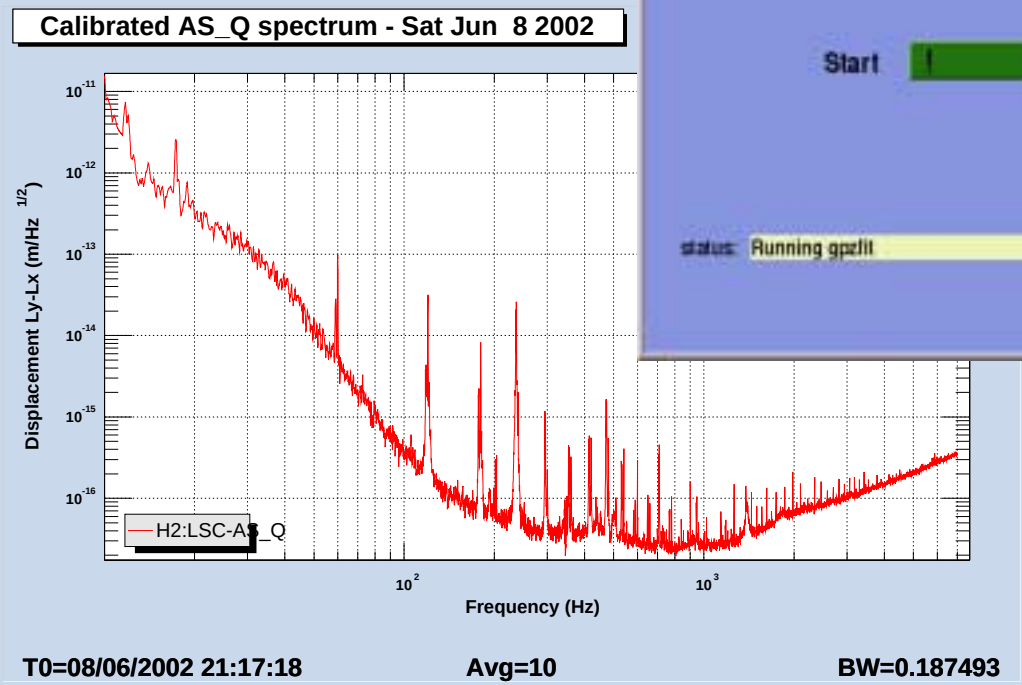
(M. Evans)



“One-click” Generation of Calibrated Spectra (M. Landry)

- uses most recent actuation calibrations
- makes swept sine measurement of transfer function from TM drive toAS_Q
- pole-zero fit using Root
- measures AS_Q spectrum and applies calibration

DTT software package by D. Sigg

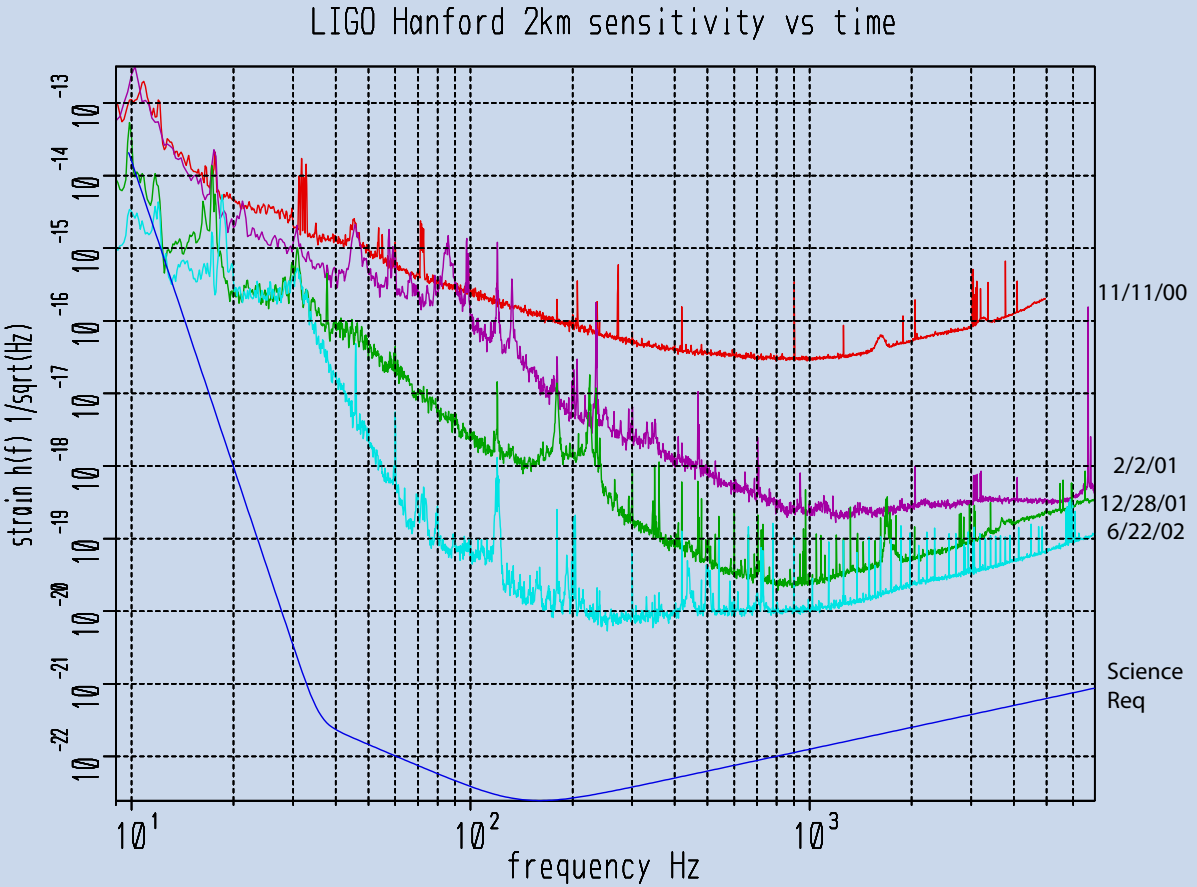


LIGO

LHO 2k Interferometer Status

- 5 Watts laser power delivered to modecleaner.
  - » Attenuation at AS port gives 20-40 mW effective power
- Recycling factor 15-25
  - » Contaminated optic?
- Analog suspension controllers.
- Only WFS 1 active
  - » Improved optical lever damping for ETMs
- Common-mode servo configuration changed (now similar to TAMA)
- Tidal prediction applied to reference cavity temperature.
- Fine actuators (PZTs on ETM stacks) used for residual tidal compensation.
- First part of intensity stabilization loop is active.
- Automated calibration.
- Multi-hour locked stretches, often 6-10 hours.

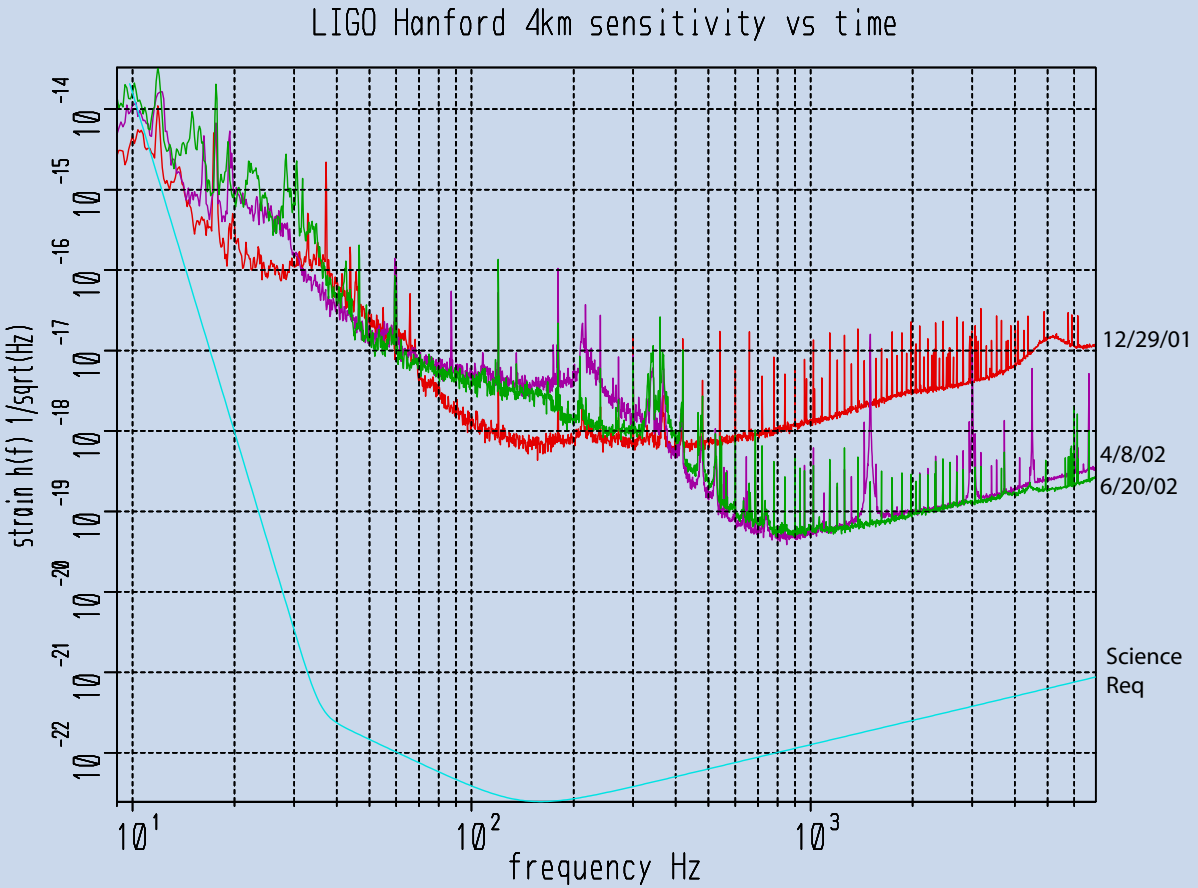
Sensitivity Improvement Hanford 2k Ifo.



LHO 4k Interferometer Status

- 1 Watt laser power delivered to modecleaner
  - » 20 mW effective at AS port
- Recycling factor 40-50
- Digital suspension controllers
  - » Lots of digital filter stages
  - » Frequency-dependent diagonalization of drive of TM drives
- Only WF1 active
- Original common-mode servo configuration
- Tidal prediction to reference cavity temperature
- Fine actuators on ETM stacks for balance of tidal.
- Inner loop of intensity stabilization active.
- Lots of code changes.
- Shakedown of digital suspension code now (almost) complete.
- Now locking for up to 8 hours.

Sensitivity Improvement Hanford 4K Ifo.

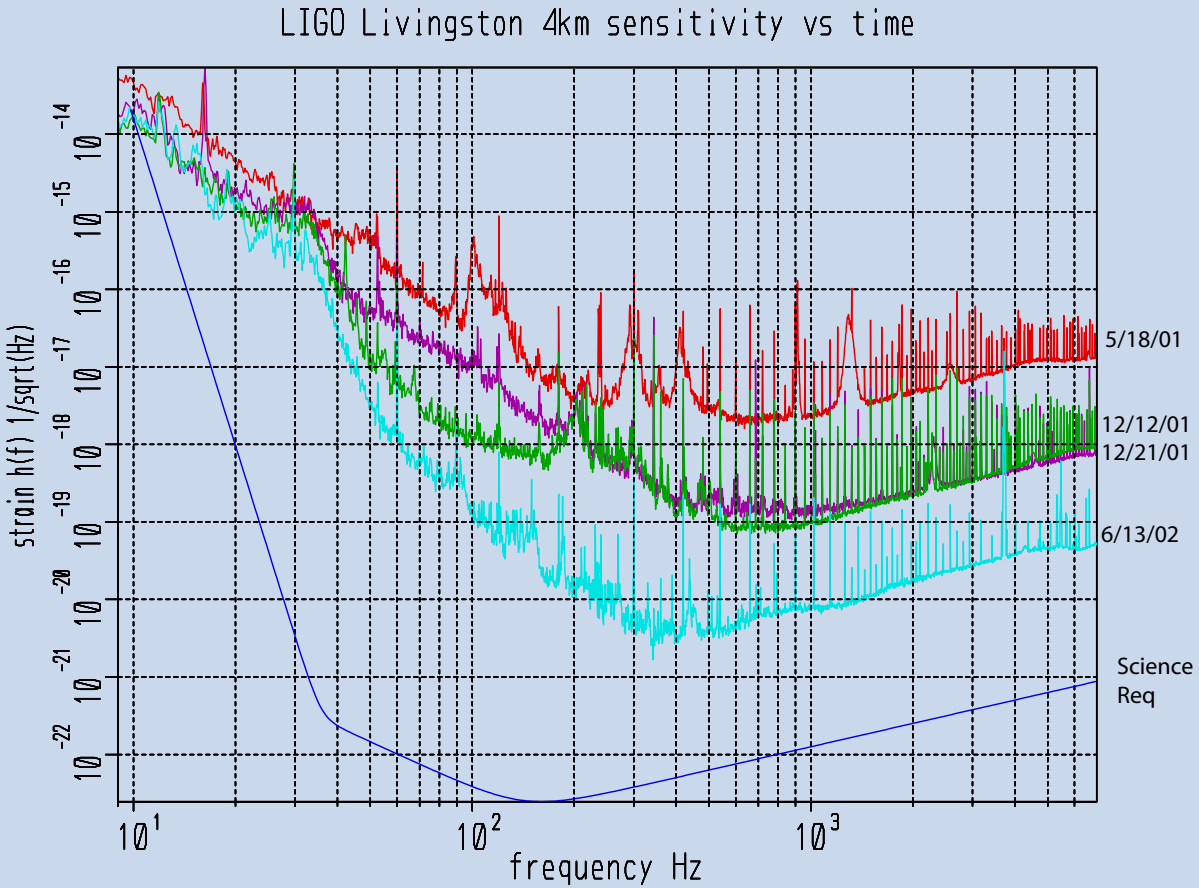


LIGO

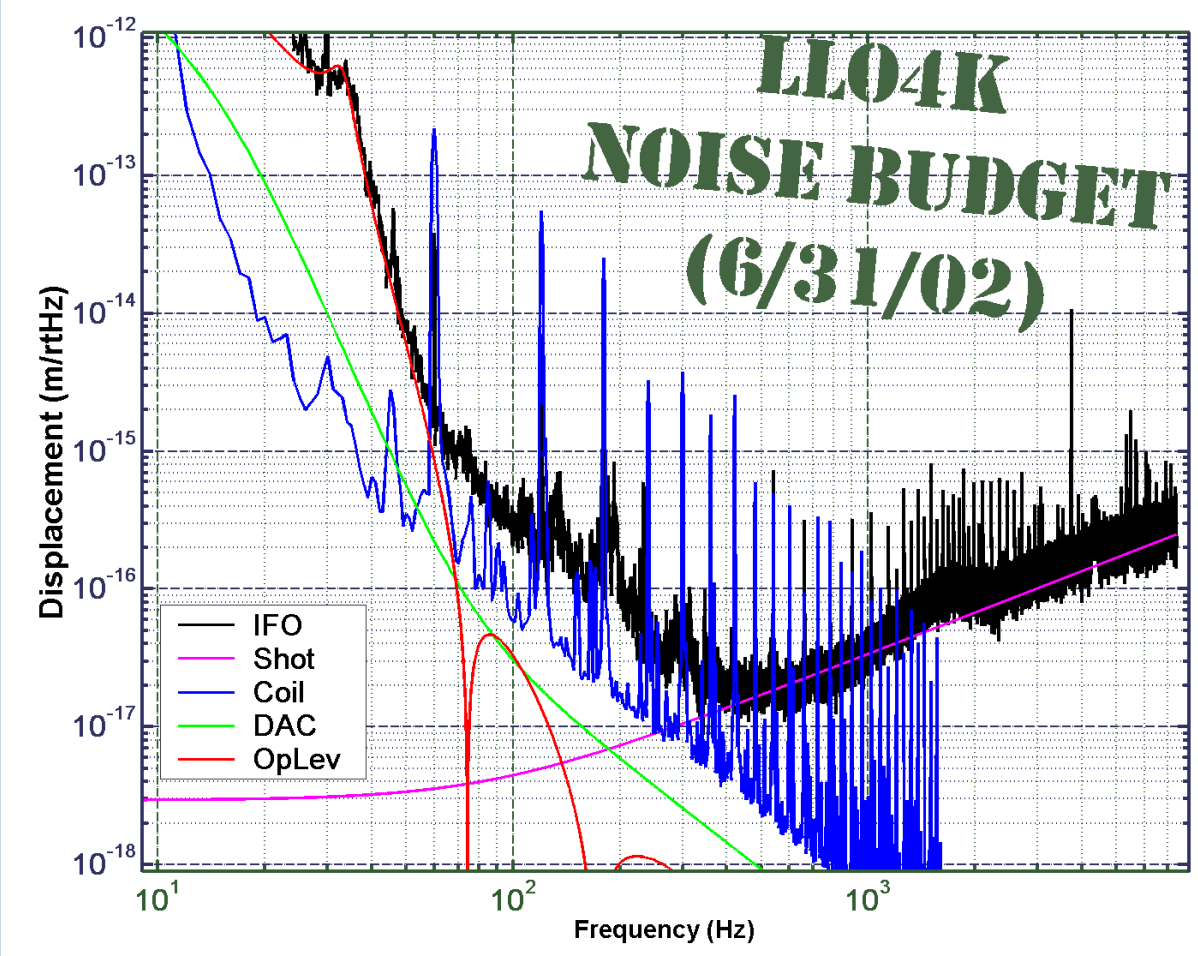
LLO 4k Interferometer Status

- 1.9 Watt laser power to MC.
- Recycling gain ~ 50.
- Analog suspension controllers.
- Original common-mode servo configuration.
- Closed-loop control of ref. cavity temp. for CM tides.
- Fine actuators for residual tidal correction.
- PEPI to reduce 0.3 –5 Hz seismic noise at ETMs
- Feed-forward to ETMs to reduce large microseism.
- Inner loop of intensity servo active.
- Unable to lock during logging – most weekdays.
- Adversely affected by traffic on highway.
- Lock broken by trains twice nightly.
- Locking for multi-hour stretches when noise allows.

Sensitivity Improvement Livingston 4k Ifo.



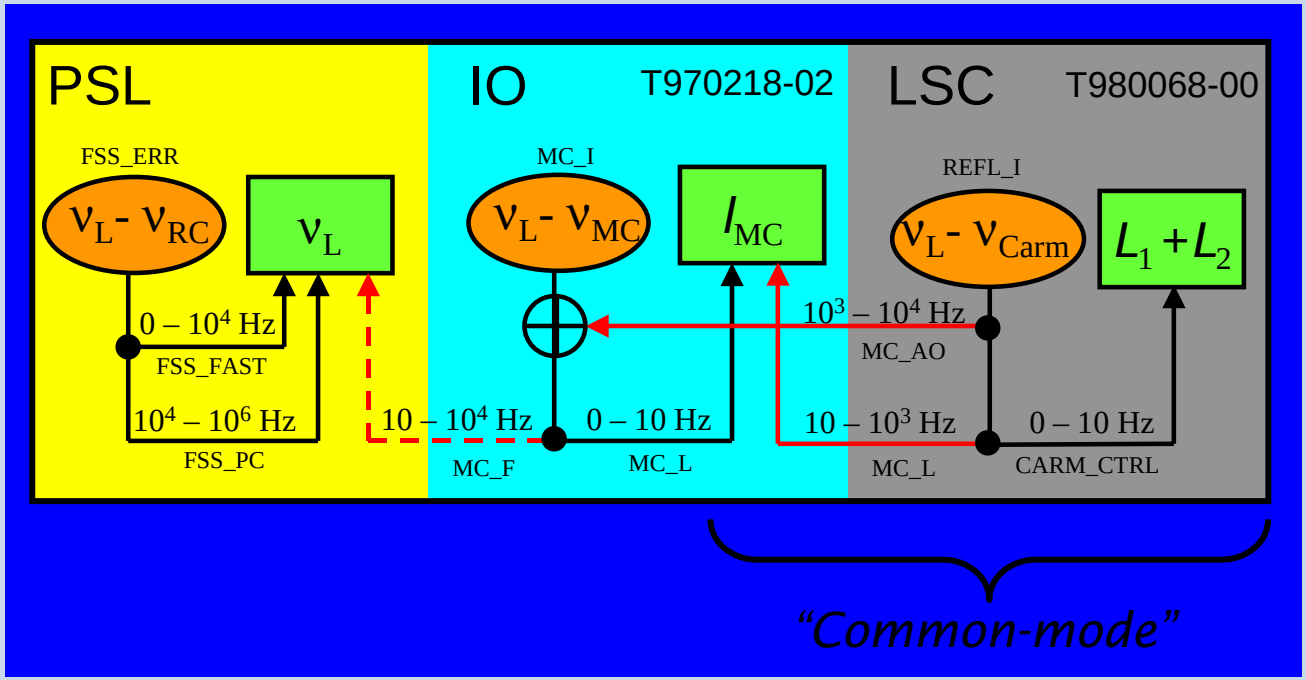
Interferometer noise modeling (R. Adhikari)



- EO shutter at AS port attenuates light by factor of 50
- New optical lever whitening filters should reduce ADC noise by factor of 400
- Below 15 Hz, freq. noise resulting from MC radiation pressure fluctuations dominates

2k Sensitivity Improvement: Reconfiguration of CM servo

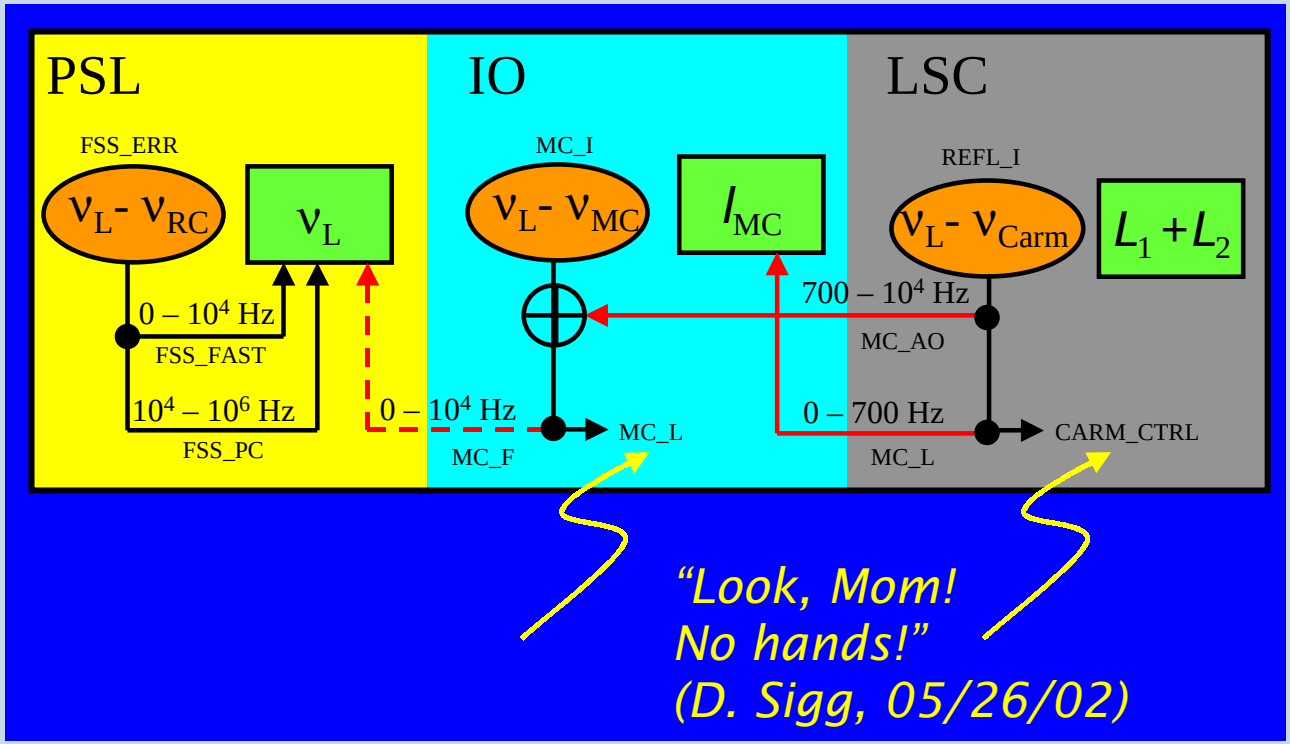
- Original configuration of frequency stabilization topology



From Nergis M.

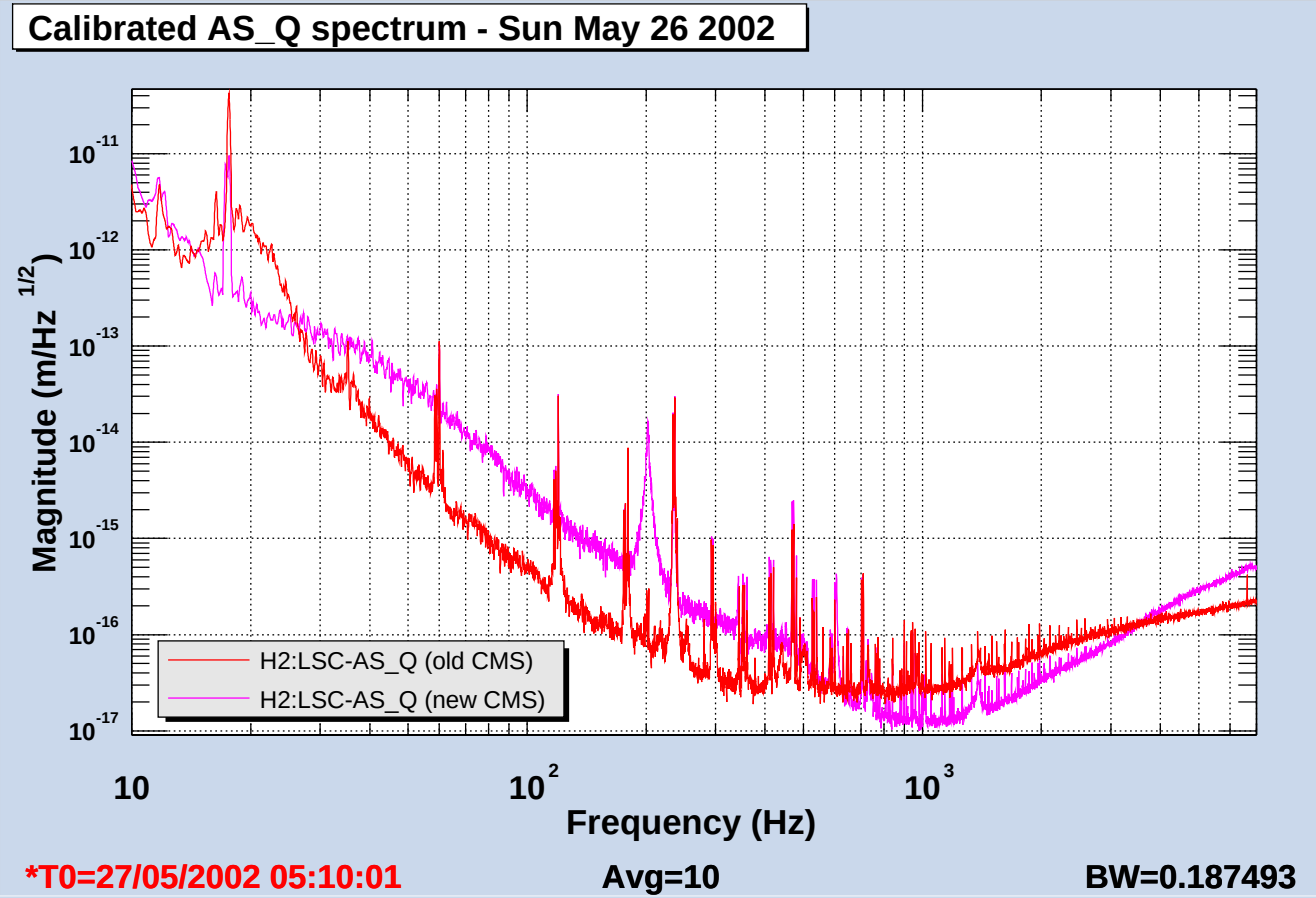
Reconfiguration of Common-mode Servo (D. Sigg)

- Eliminate CARM drive to ETMs
- MC servo feedback to laser frequency actuator only

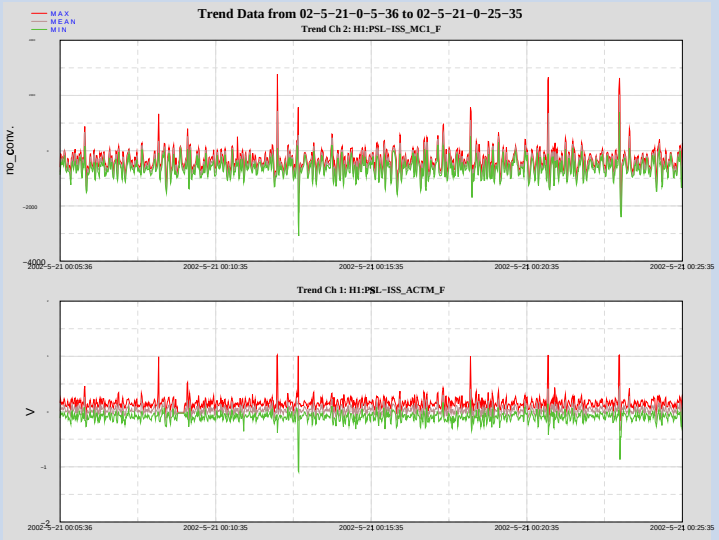


From Nergis M.

Improved Displacement Spectrum

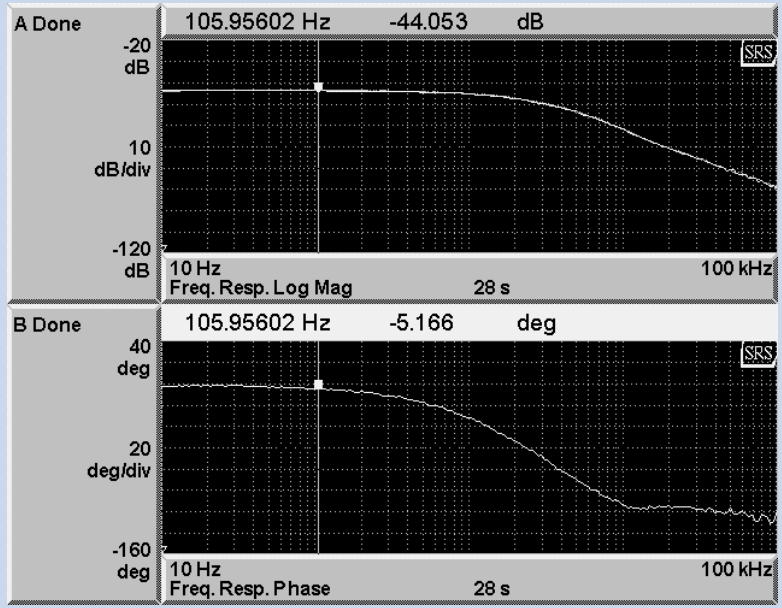


Relative Intensity Noise Stabilization



- Free-running slow power variations ~1-2%
- Insufficient drive range, causing power glitches (with Y. Aso, 5/02)

4k laser current shunt xfer. fctn.



D.C level = 1.7 V → 0.37%/V

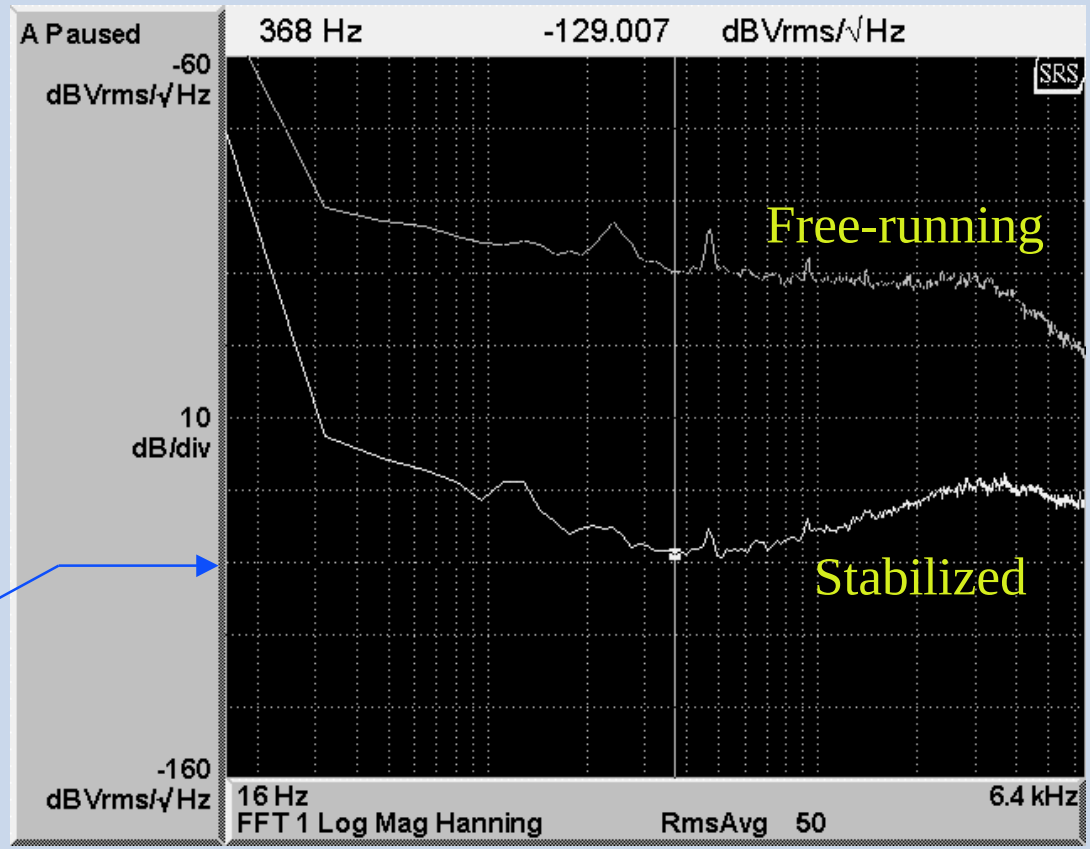
- Design range > +,- 2.5%

New Intensity Stabilization Servo

- New two-loop servo and new low-noise photodetectors
- Inner loop with PD just after pre-modecleaner
- Outer loop with PD just after modecleaner (outside vacuum)
- RIN goal: 1e-8/rtHz
- Only inner loop installed, June, 2002
- +,- 10 V drive range

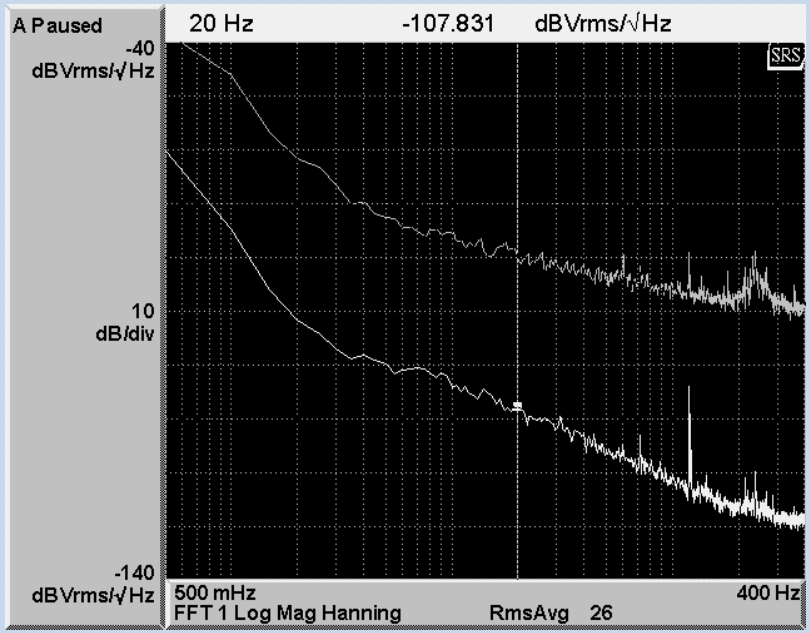
$\Delta P/P = 5e\text{-}8\ Hz^{-1/2}$

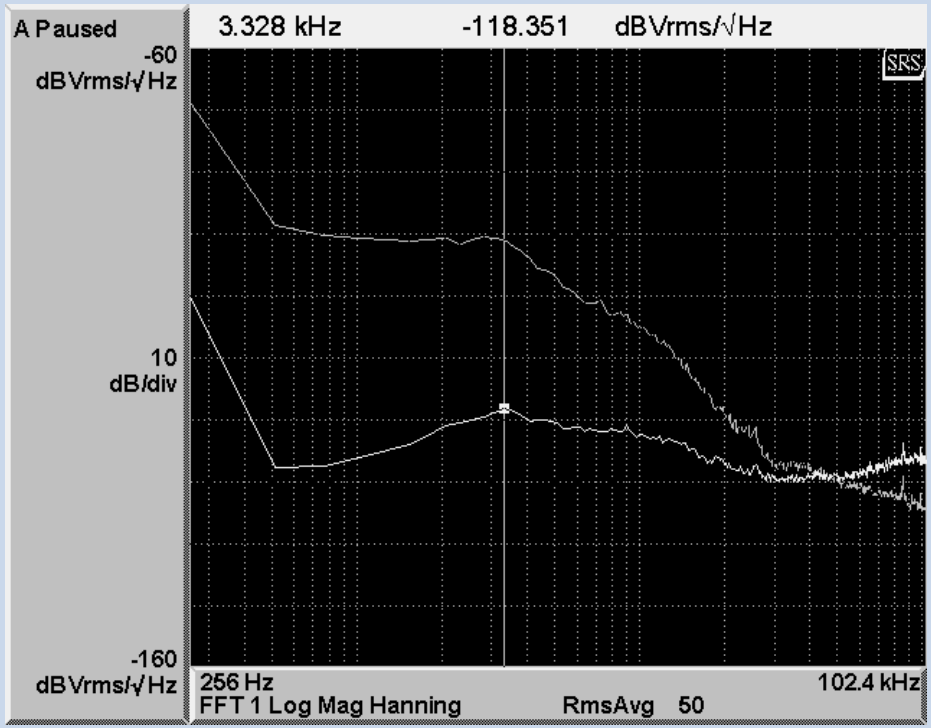
LHO 4k Outside-the-loop RIN Spectra



LHO 4k RIN Spectra

Gain ~ 30 dB at 1 Hz

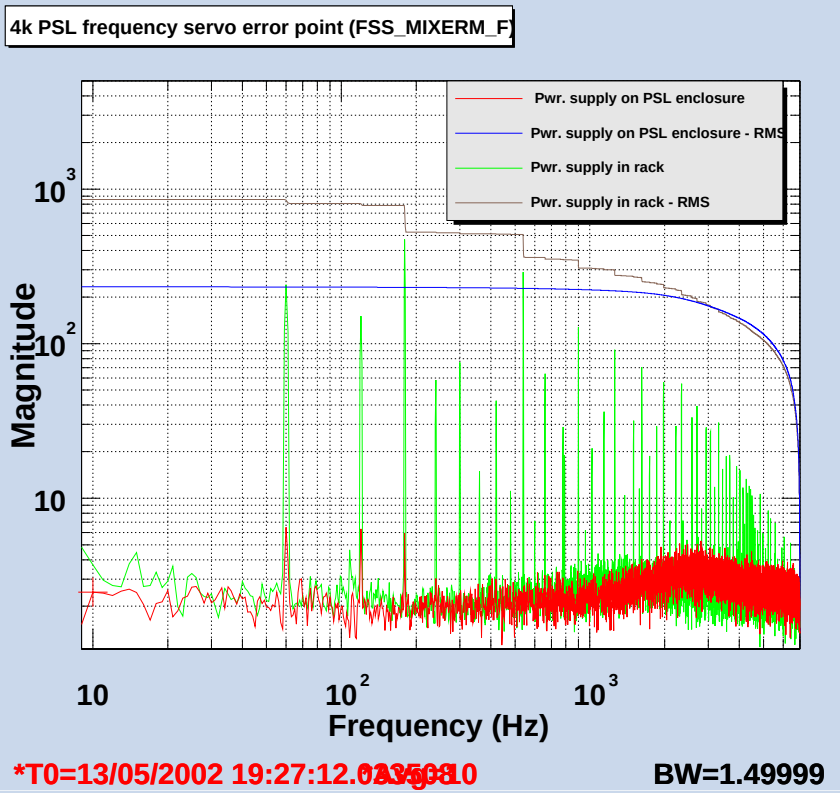




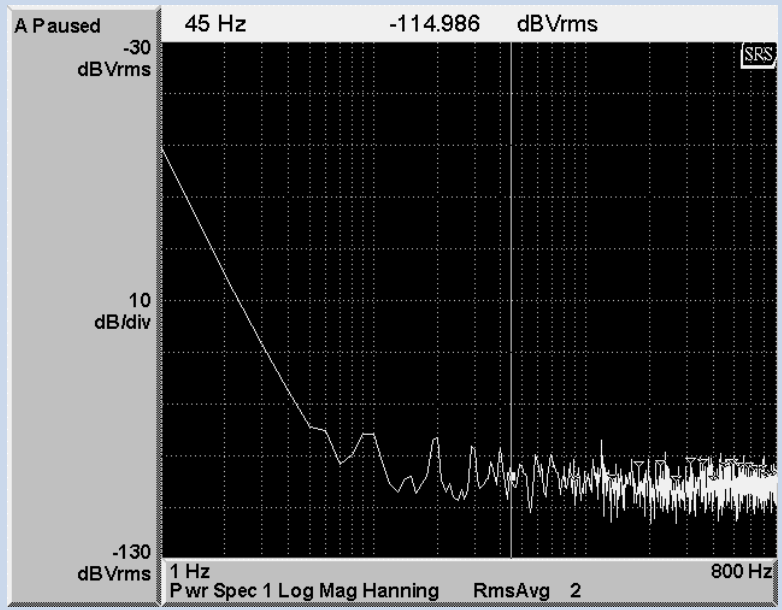
RIN not yet measured downstream of MC with this servo.

Grounding and EMI

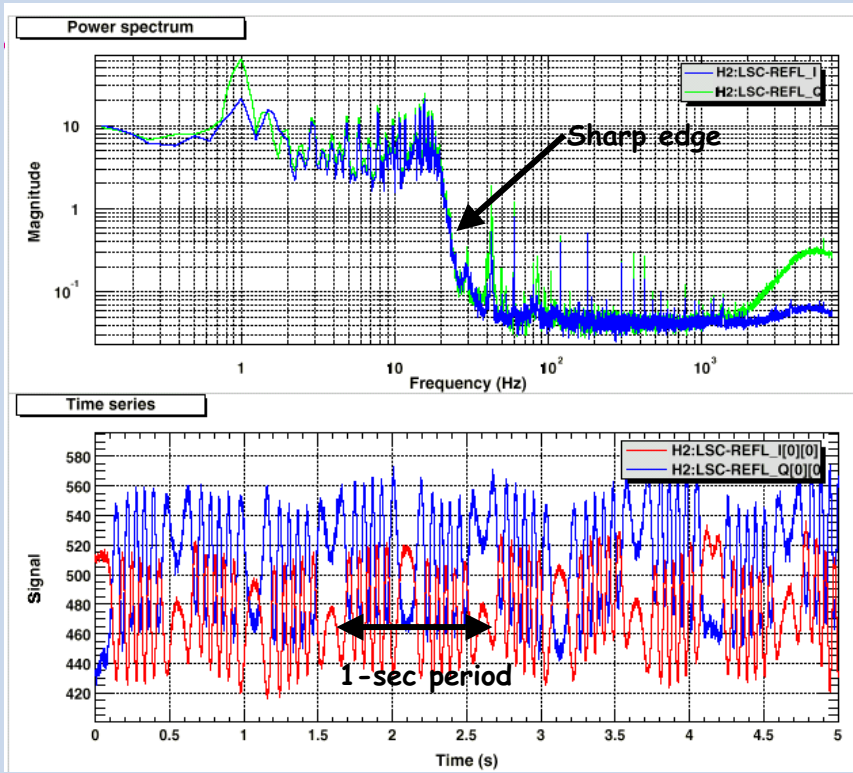
60 Hz and harmonics



- Frequency stabilization servo error point
  - » **Green** – laser power supply in rack
  - » **Red** – laser power supply moved to top of PSL enclosure

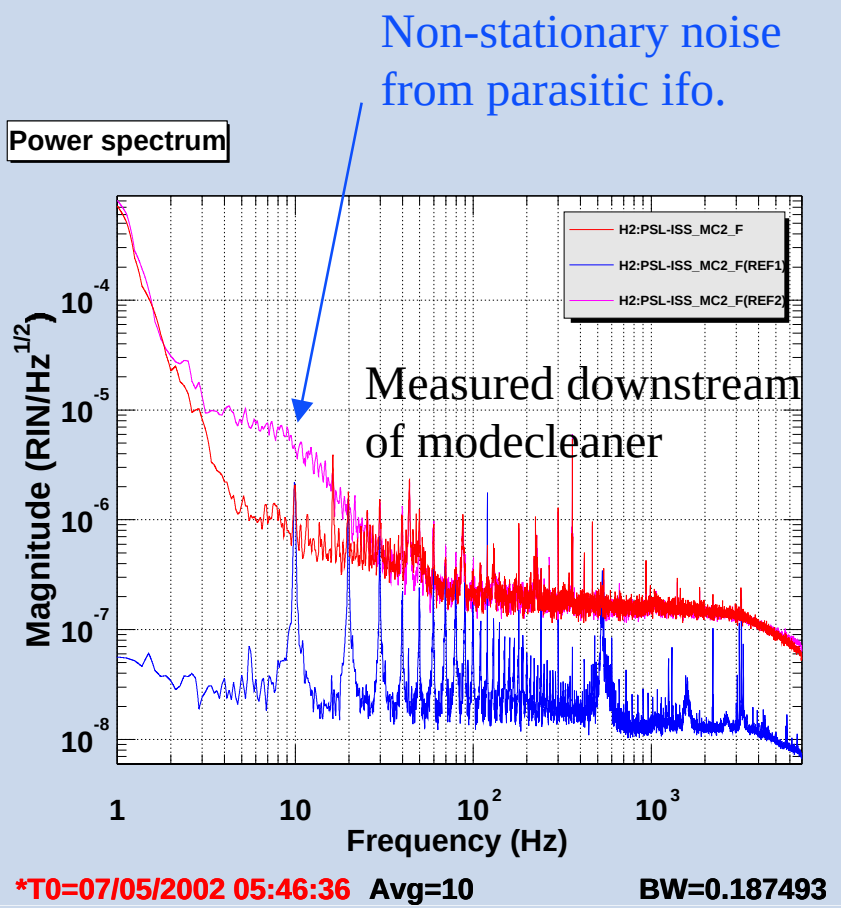


Parasitic Interferometer LHO 2k

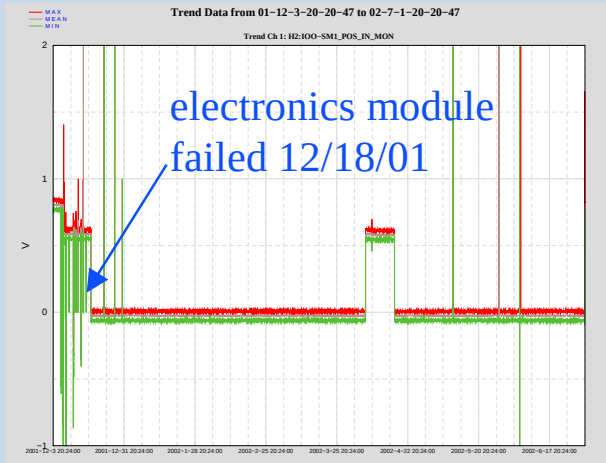


- Measurement made with RM aligned and other optics misaligned
- 1 Hz period indicates small optic motion
- 6 fringes >> 3 microns$_{peak}$
- Tried to identify which optic moving by changing damping gains – no change observed
- Investigaion abandoned because edge is below seismic wall

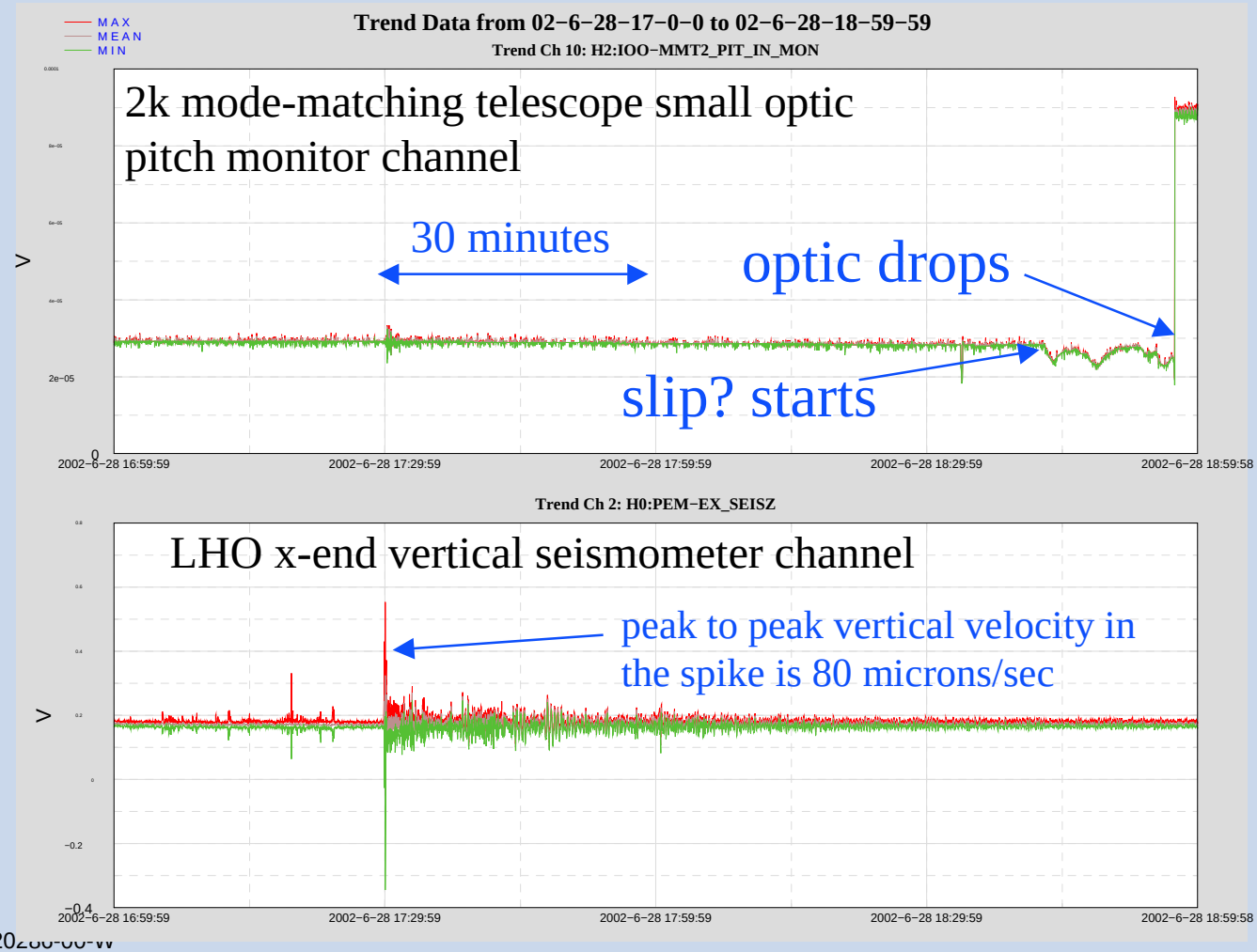
Source of Parasitic Interferometer Identified?



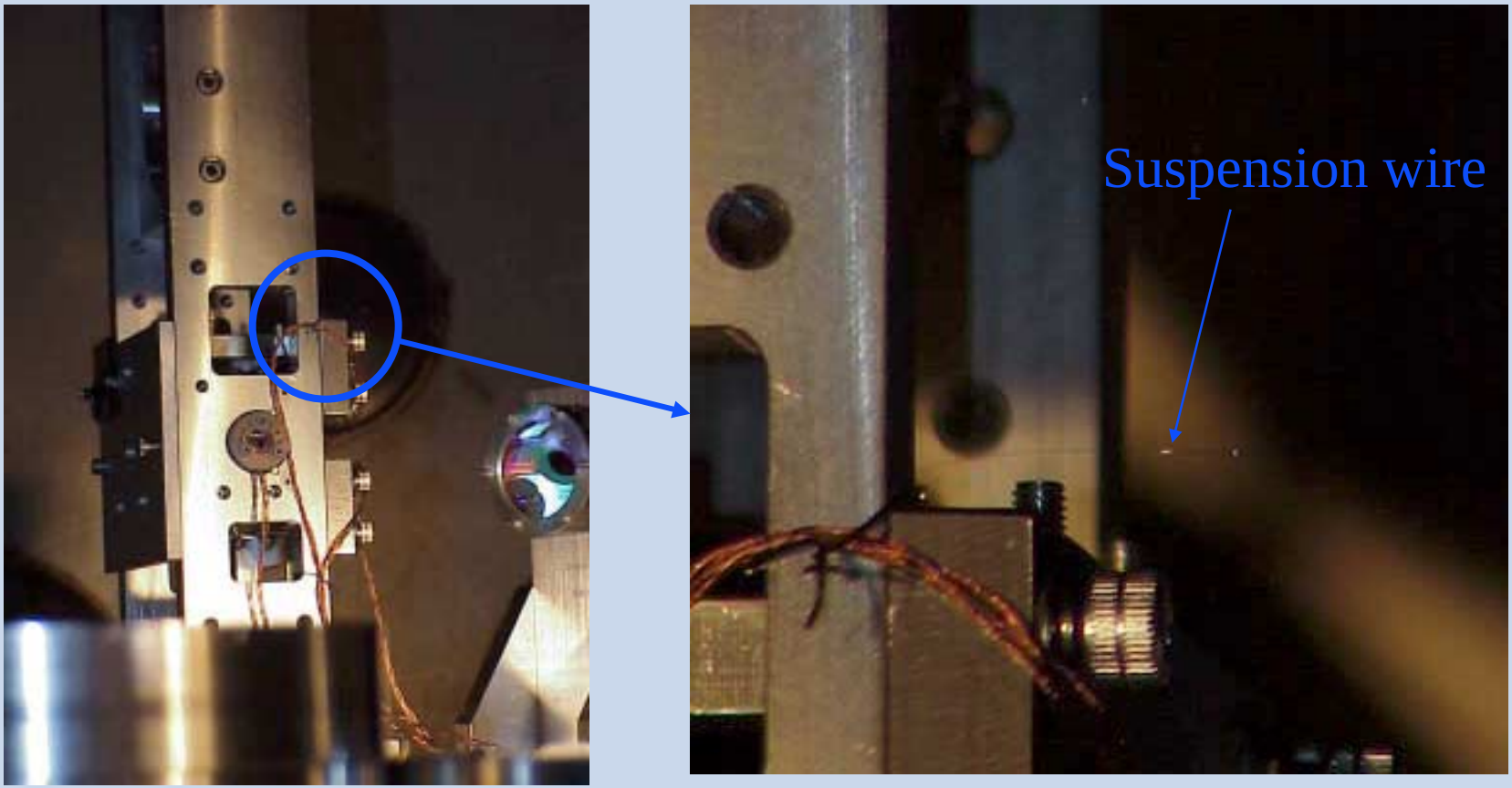
- Post MMT2 slippage investigation
  - » "uncovered an unsettling scenario. From the plots, **SM1** has been without it's photodiode sensor readbacks (and damping) since ~12/18/01." J. Myers July1, 2002 elog entry



Delay of S1 Run
Friday, June 28, 2002



Slack MMT2 Suspension Wire



Repair of MMT2 Suspension

"A preliminary inspection of mirror MMT2 shows two broken magnet assemblies. The wire break is along the free section of wire, not in the clamp. The optic is on its way to the optics lab for a post-mortem and repairs. Chamber door is going back on and we hope to be pumping soon."

Fred Raab7/2/02

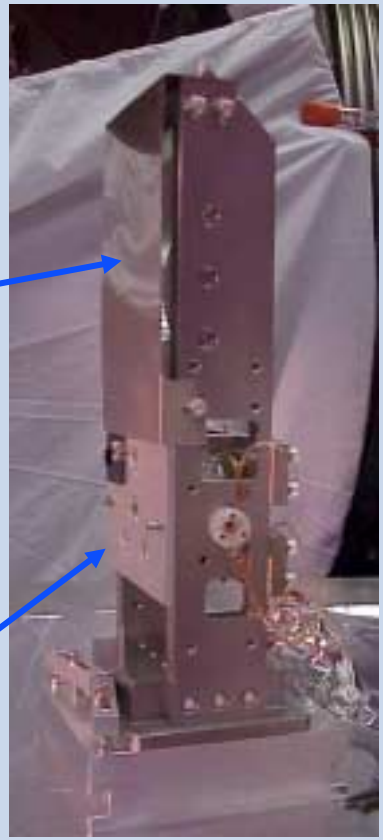
- Earthquake stops did not prevent magnet breakage – re-design underway.
- Working hypothesis is that the loss of control of one of the other optics (SM2) caused the laser beam to hit the suspension wire of MMT2, precipitating the breakage.
- Tests of breaking wires under load with hot irons appear to support this hypothesis.
- New baffles to protect suspension wires designed and implemented.

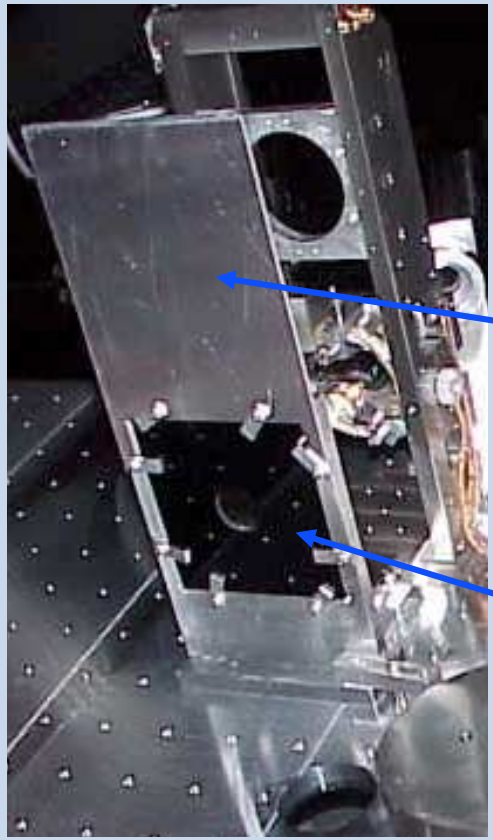
New Baffles to Protect Suspension Wires from Laser Beams

MMT2

New baffle

Alignment fixture





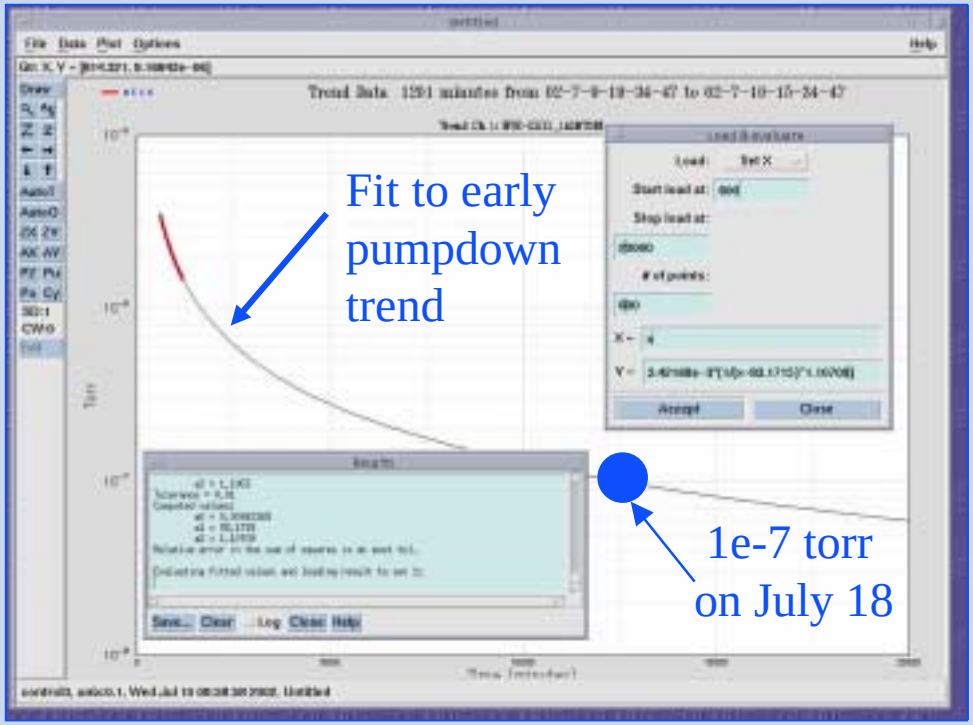
MC2

Baffle extension

Black glass baffle

Pumpdown

- MMT2 repaired and re-installed
- Pumpdown began at 12:35 PST on July 9.



- Waiting for water vapor pressure to decrease so that gate valves to beam tubes can be opened.
- Preliminary alignment, centering on Faraday isolator, etc., looks good.
- It looks like the S1 run will begin the day after the LSC meeting on August 23, 2002.

After the S1 Run

- Still lots to be done!
- Many pending hardware and software installation tasks

software | software & hardware | hardware | ✔ = to do

Installation Task	L1	H1	H2
new LSC code (generic filter modules)		✔	
new ASC code (generic filter modules)		✔	
Code updates: add test points, channel name changes	✔	✔	✔
DSC system	✔		✔
PEPI on ITMs	✔		
Microseismic FF		✔	✔
AS port table re-layout & auto-alignment sequencing	✔	✔	✔
Optlev WH filter	✔	✔	✔
Pentek Diff. DRV/RCV	✔	✔	✔
ISS outer loop	✔	✔	✔
RFI cleanup/electronics infrastructure rework	✔	✔	✔
Core optics fix			✔
Add AS port LSC PDs	✔	✔	✔
Photon calibrators	✔	✔	✔

New Design Tasks
LSC Dewhitening filter: stage-by-stage, smooth turn-on ?
Mode cleaner servo: incorporate revs, fix flaws, digital MC_L path
Common mode servo: incorporate revisions
PSL FSS board: incorporate BW increasing revs
DSC-compatible coil driver for LLO
RFI cleanup & grounding solutions
WFS auto-centering system (ISC table beam stabilization)
Stabilize input beam pointing

P. Fritschel 6/02

LIGO Run Plan

- Science 1 run – Upper Limits
  - June 29 to July 15 (Delayed)
  - 2.5 weeks comparable to E7
  - Target sensitivity: 200x design
- Science 2 run – Upper Limits
  - Nov. 22 to Jan. 6, 2003
  - 8 weeks
  - Target sensitivity: 20x design
- Science 3 run – Search Run
  - July 1, 2003 to Jan. 1, 2004
  - 26 weeks
  - Target sensitivity: 5x design

- "During 2003 and 2004, we will plan to run in this search mode for at least 50% of the calendar time, followed by the planned one year integrated LIGO science run at design sensitivity. This science run will be completed prior to proposed major interferometer replacements."

LIGO Lab Planning Memo.