LIGO

Commissioning Report

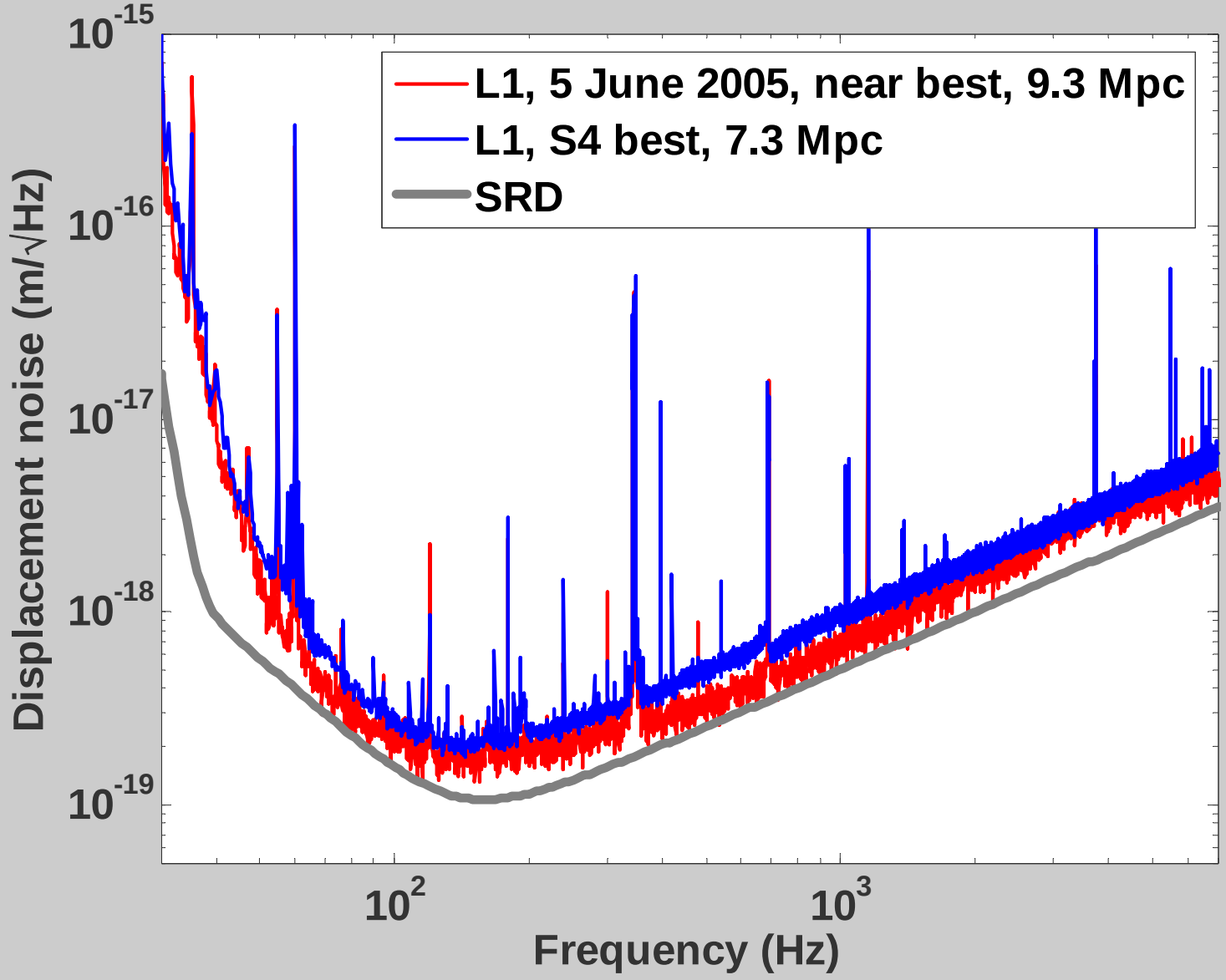
P Fritschel

LSC meeting, LHO

15 Aug 2005

G050371-00-D

LIGO

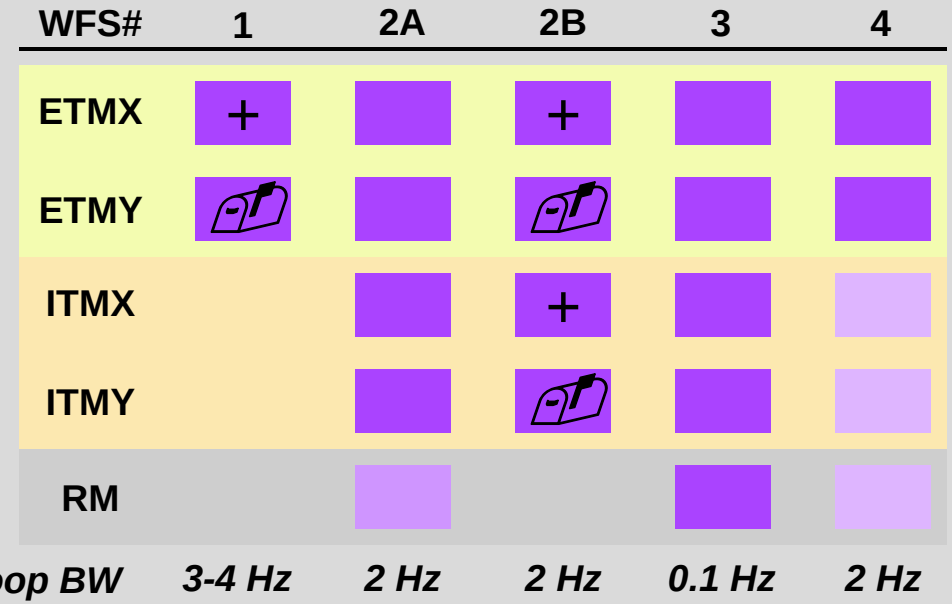

L1, 5 June 2005, near best, 9.3 Mpc
L1, S4 best, 7.3 Mpc
SRD
Displacement noise (m/√Hz)
10^-15
10^-16
10^-17
10^-18
10^-19
10^2
10^3
Frequency (Hz)

Sensitivity improvements (L1)

- Input laser power increase: 2 W (S4) to 6 W
  - Increased bandwidth of the alignment servos (WFS)
  - Laser replaced, input optics efficiency improved
- TM electronics noise reduction
  - Coil drivers
  - Pointing control currents (bias modules)
- 60 Hz mitigation
- Angular controls noise reduction
  - Better decoupling from DARM
  - Electronics noise improvements & better filtering
- Auxiliary length DOF: MICH and PRC
  - Higher power detection port (improved shot noise)
- Higher bandwidth laser frequency and power stabilization loops
- Watching out for photodiode damage!

WFS servo bandwidth increase

- System measures & controls mirror (core optic) pitch & yaw angles
  - Complication: each sensor is sensitive, in general, to multiple mirrors
  - In the past, destabilizing interactions were avoided by keeping the servo bandwidths very low (except for WFS 1)
  - Now: mixing of control signals is carefully tuned to decouple the WFS channels from each other:



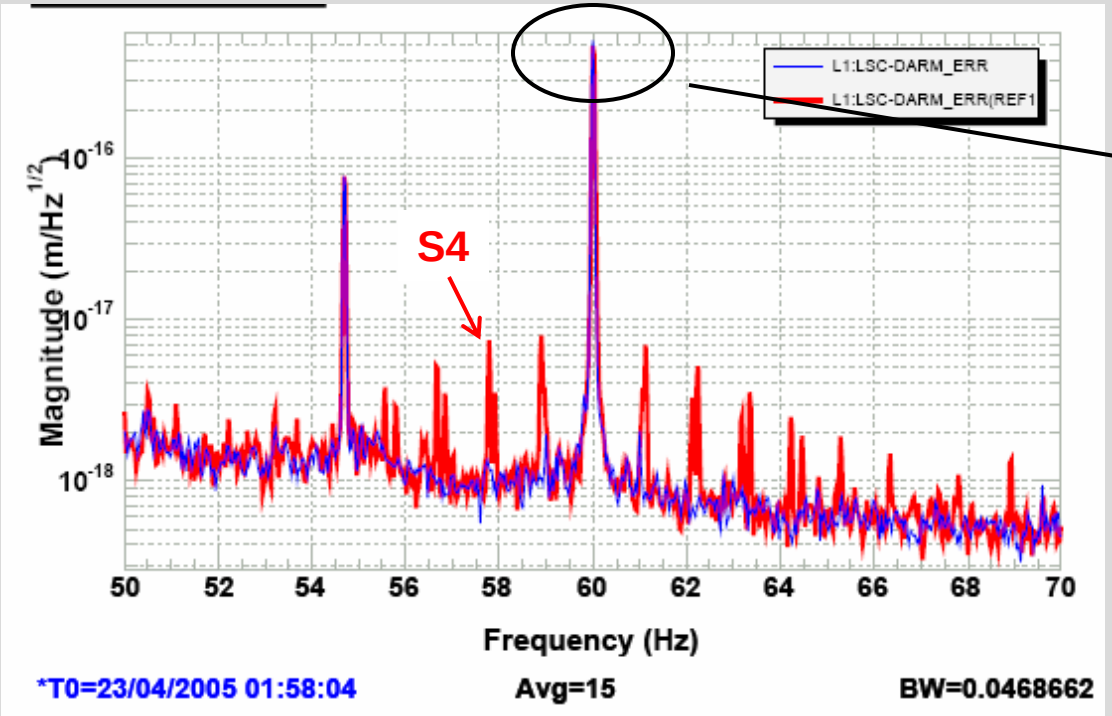
- ***Biggest benefit:*** reduces the orthogonal phase signal at the anti-symmetric port (ASI), allowing higher power operation

Laser power: woes & triumphs

- L1: laser replaced after S4 with a recently refurbished unit
  - Failed shortly after installation
  - Replaced with another refurbished unit (sent from LHO)
  - Optical efficiency from laser output to mode cleaner input significantly increased
    - Replaced pre-mode cleaner, optimized components, …
    - Close to 80% efficiency from laser to input to vacuum
  - Max input power now 8 Watts
- H2: power amplifier still the original unit from Dec ’98
  - Replacement with refurbished unit is imminent
- Lightwave Electronics acquired by JDS Uniphase several months ago
  - Has delayed the repair of our lasers: *currently have no 10 W spares in-house*

60 Hz mitigation on L1

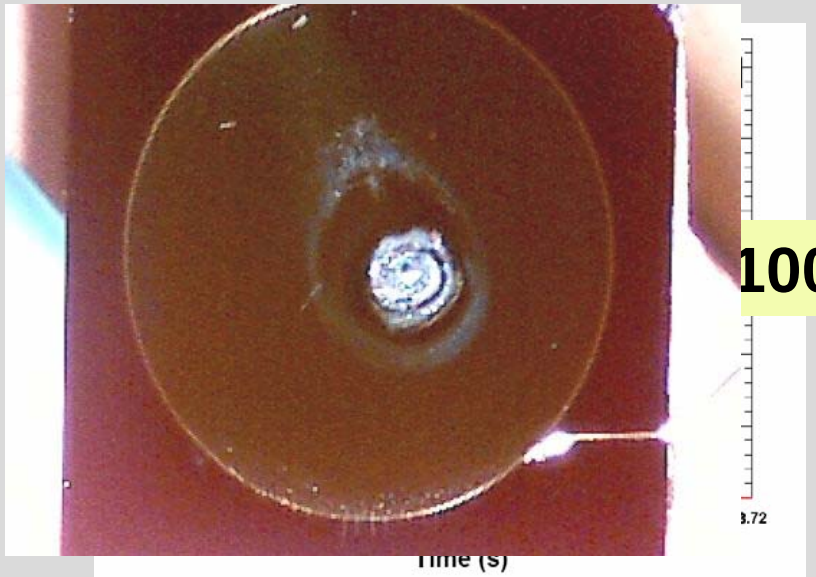
- Long-known problem: ~1 Hz SCR pulsing of end-station heater currents, picked up in DARM
- Fix: new control boards that allow ON/OFF control (already done at LHO)

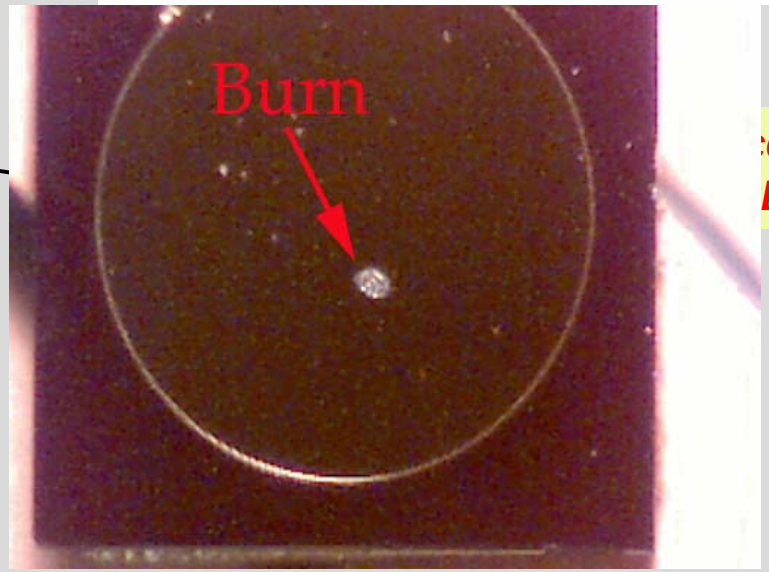


60 Hz peak later reduced by a factor of 2, by turning off a pipe heater in the Y end station; now 5×10^{-17} m-rms

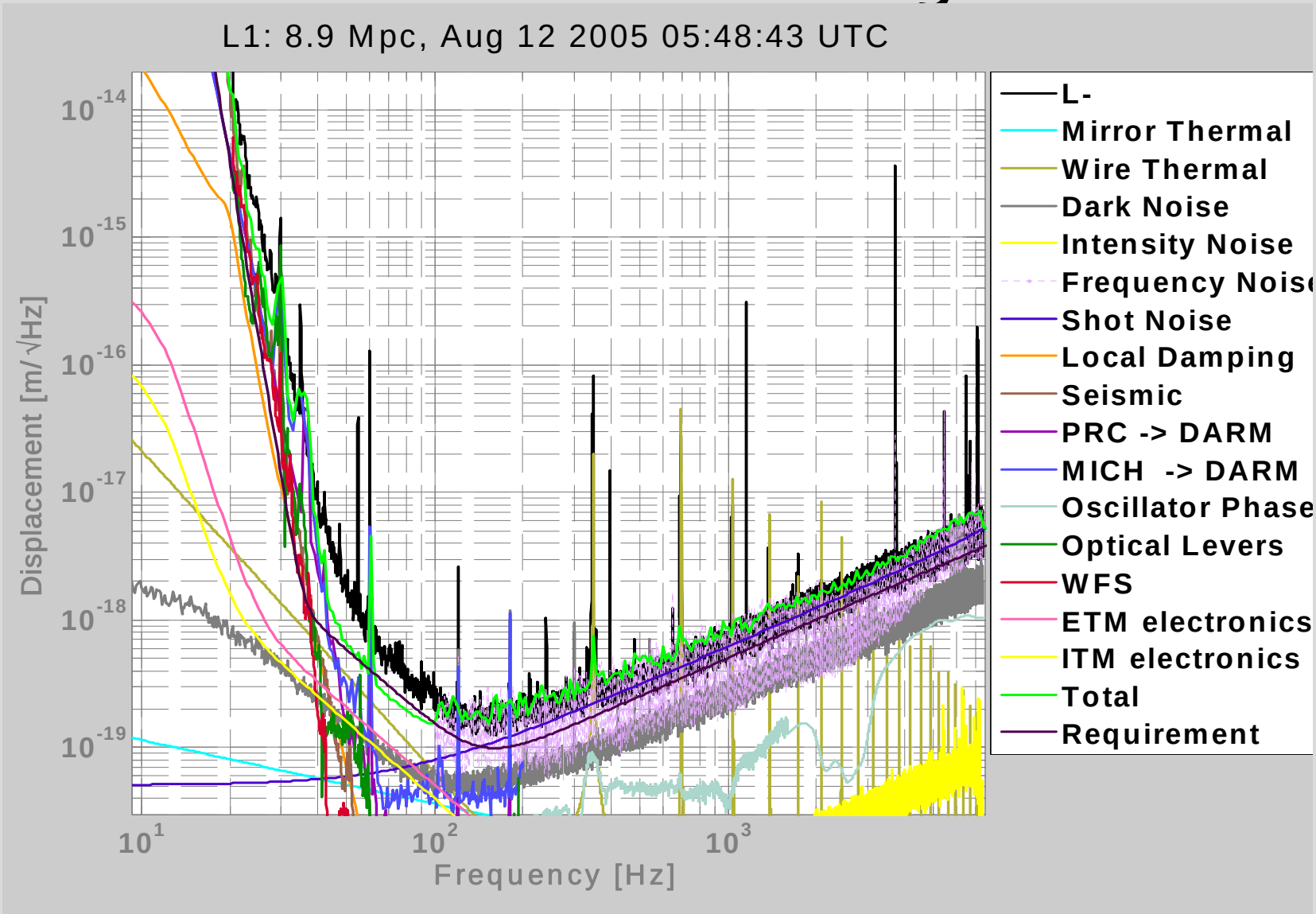
Ongoing story of photodiode damage

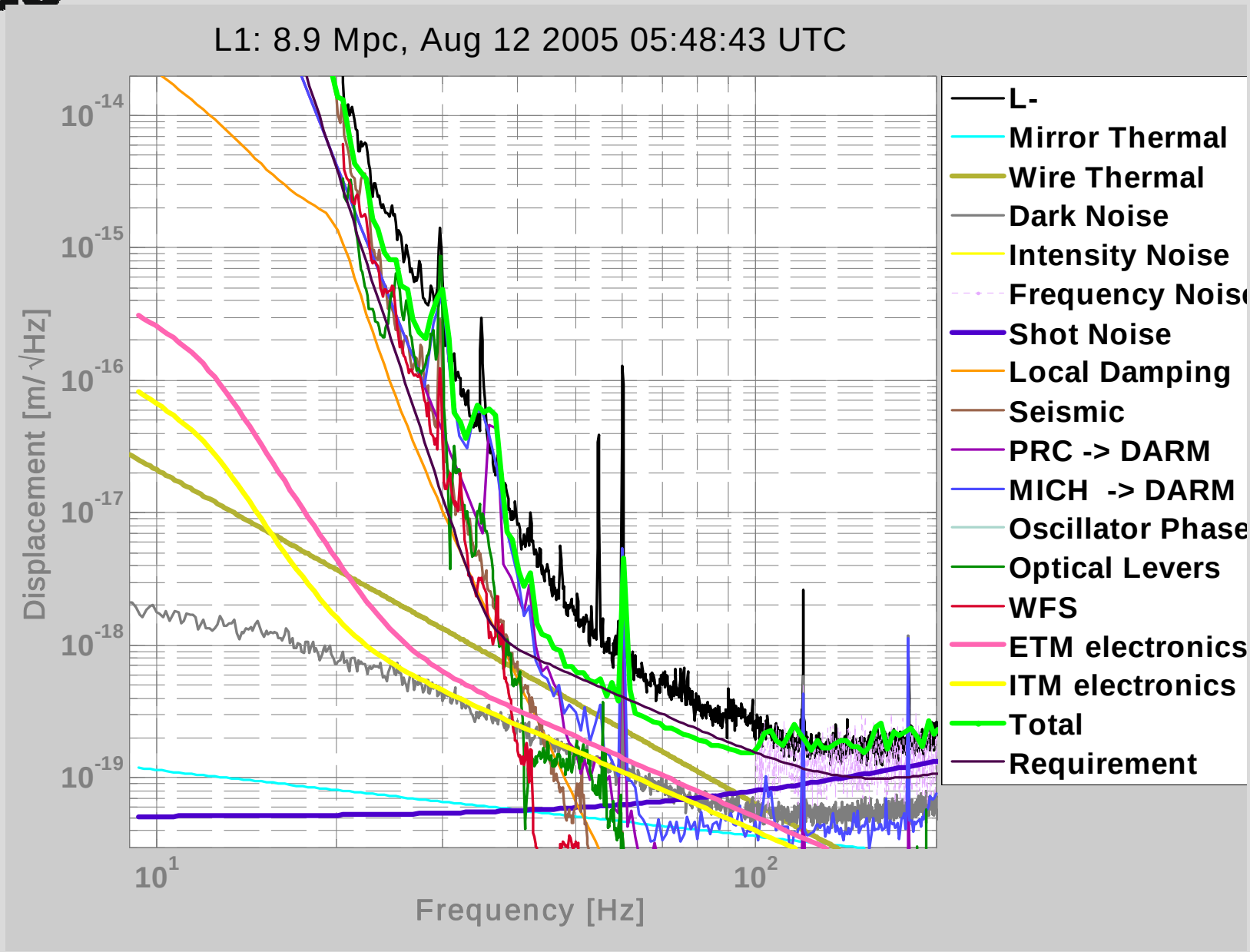
- Loss-of-lock: full beamsplitter power can be dumped out the AS port, in a ~10 msec width pulse
  - Mechanical shutter cuts off the beam, with a trigger delay of about 6 msec
- PD damage due to
  - Too high trigger level
  - Shutter too slow (wrong type)
- Damaged PDs can be noisy
- Solution (in progress):
  - All shutters of proper type
  - Carefully set trigger level
  - Looking at cutting off PD bias voltage on lock-loss





L1 Noise Budget

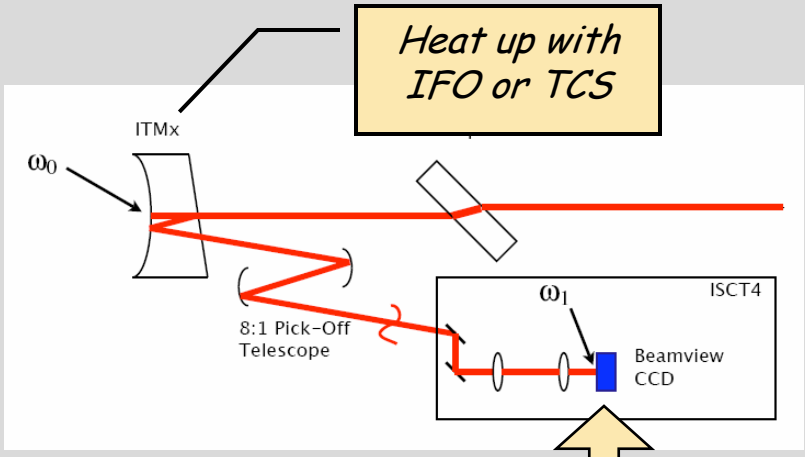



L1: 8.9 Mpc, Aug 12 2005 05:48:43 UTC
Displacement [m/√Hz]
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^1
10^2
Frequency [Hz]
L-
Mirror Thermal
Wire Thermal
Dark Noise
Intensity Noise
Frequency Noise
Shot Noise
Local Damping
Seismic
PRC -> DARM
MICH -> DARM
Oscillator Phase
Optical Levers
WFS
ETM electronics
ITM electronics
Total
Requirement

H1: high ITM absorption

- S4: operated at 3 W input, with lots of TCS compensation
  - 1.5 W of annulus TCS power on ITMX: maxed out on CO2 laser power

- Post-S4: carried out a program of in-situ characterization of optics
  - Arm cavity g-factor m'ments: changes under thermal loading
  - Beam spot size changes
  - Absorption results:
    - ITMX: 35 mW/W, or about 20ppm on the HR surface
    - ITMY: 13.5 mW/W, or about 8ppm on the HR surface



- Post-S4: attempted to operate at higher input power, with more TCS
  - Bought & installed a higher power CO2 laser for ITMX

Dealing with H1 absorption

- Strategy: gave until mid-June to achieve 10 Mpc sensitivity with the absorptive ITMX
  - 5-6 W into MC needed to achieve this
  - Hours long locks at 6 W achieved, but power levels not stable
  - No sensitivity improvement over S4
- Mid-June: decided to replace ITMX
  - Spare had been fully characterized at Caltech (Liyuan Z, Garilynn) in the preceding months
    - Scattering, bulk & surface absorption, surface figure
  - Decided to also try *in-situ* drag wiping of ITMY
  - Vent took place on 29 June
    - Took a bit longer than expected (17hr) due to problems with static charge (vented too fast?), but otherwise successful
    - Approx. 4 weeks of pumping before gate valves were opened
  - Montana earthquake hit later on 'opening day', shifted alignment of 3 optics
    - Eventually successful freeing all 3 from the outside

And now?

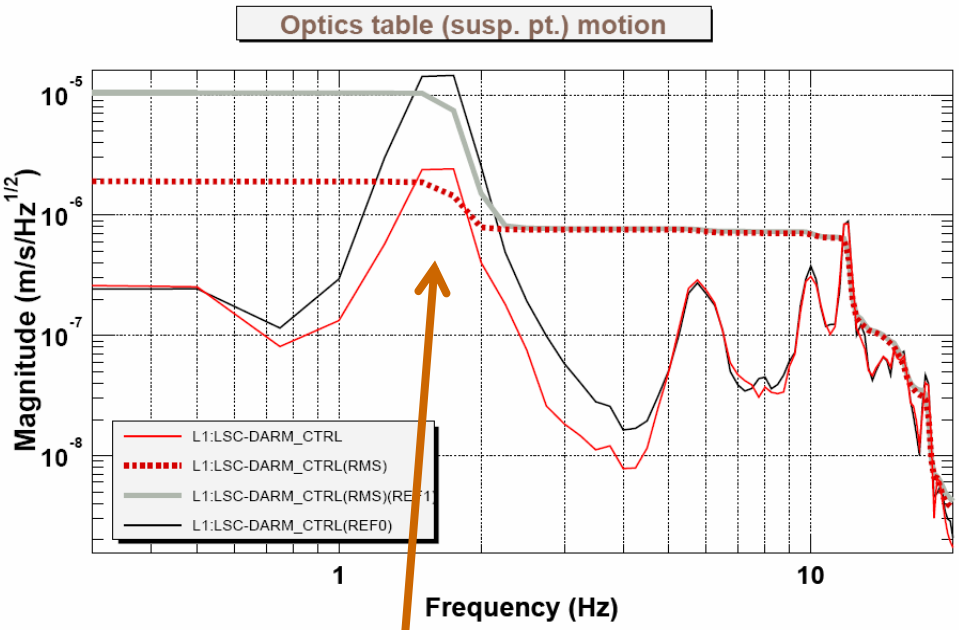
- IFO has been run at 4.5 W in MC: no annulus TCS needed, 7-8 Mpc sensitivity achieved
- Beam size measurements repeated:

	ITMX	ITMY
Before	35 mW/W	13.5 mW/W
Now	< 3 mW/W	3 mW/W

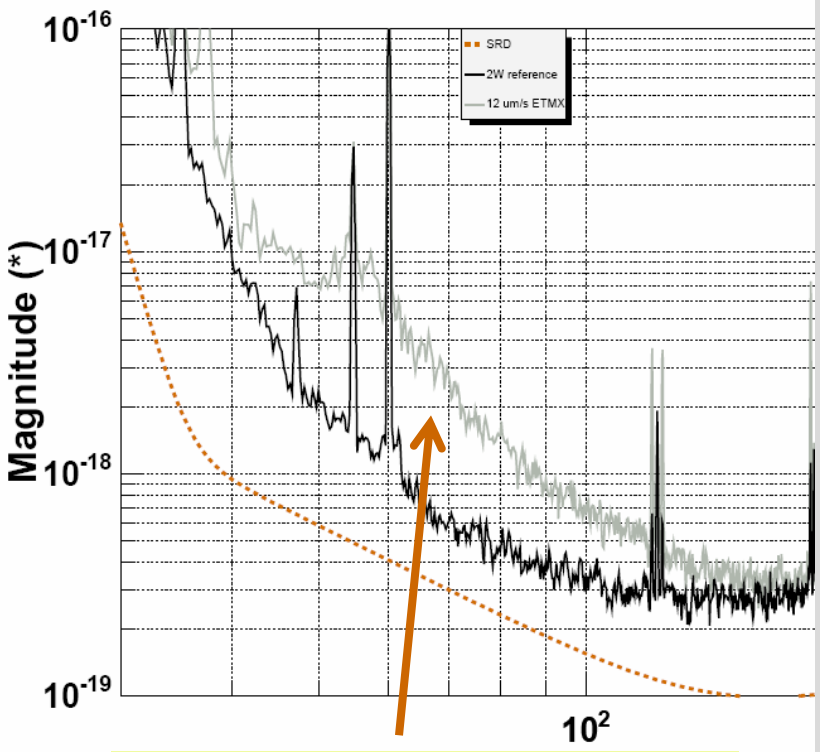
- Forensics on the extracted ITM being carried out at Caltech
  - So far no abnormal absorption has been seen!
- All in all, a very successful operation, thanks to:
  - Dave O, Rick S, Sam W, Keita K, Cheryl V, Gerardo M, Gari B, Liyuan Z, Helena A, Doug C, Betsy B, Gary T, John W, Kyle R

Upconversion from stack motion

Effect first seen at LHO, & measured recently at LLO:*



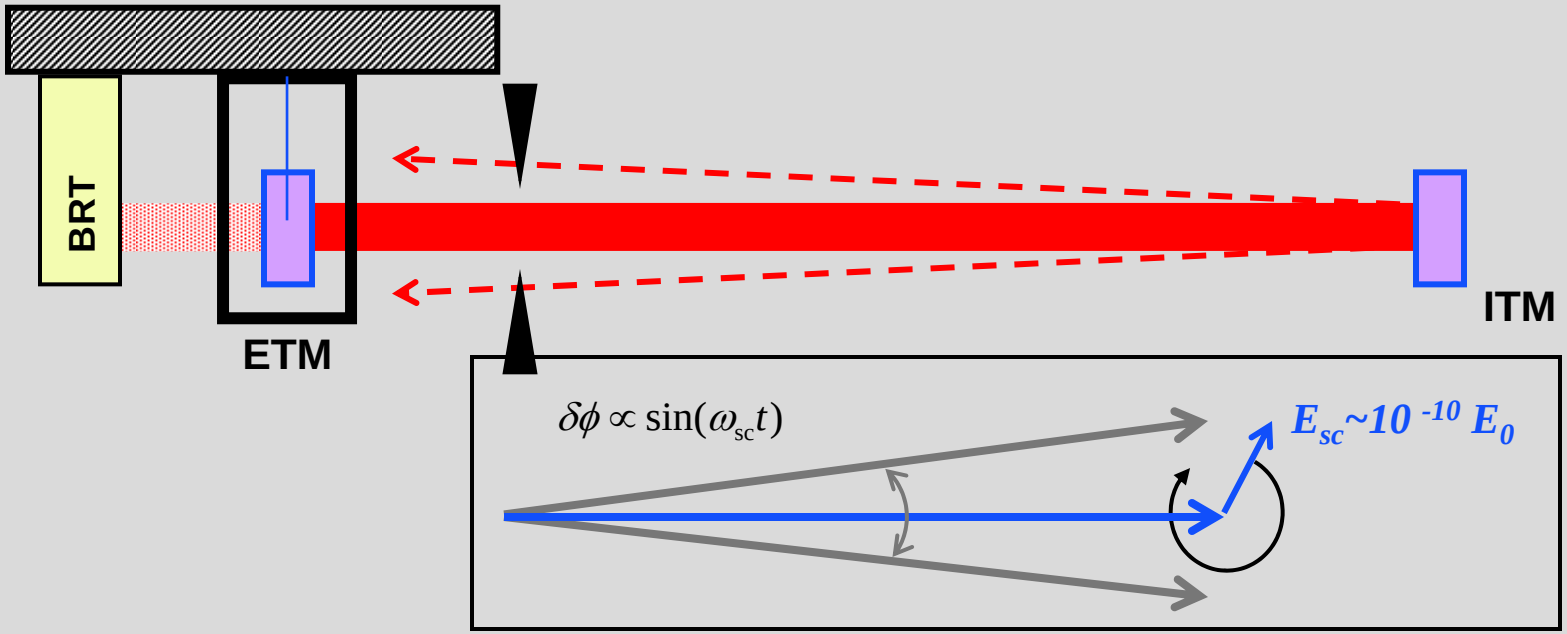
Using HEPI, increase the suspension point motion at 1.5 Hz by a factor of 5



DARM noise increases by a factor of ~5 over a wide band

**see Robert Schofield's DetChar talk*

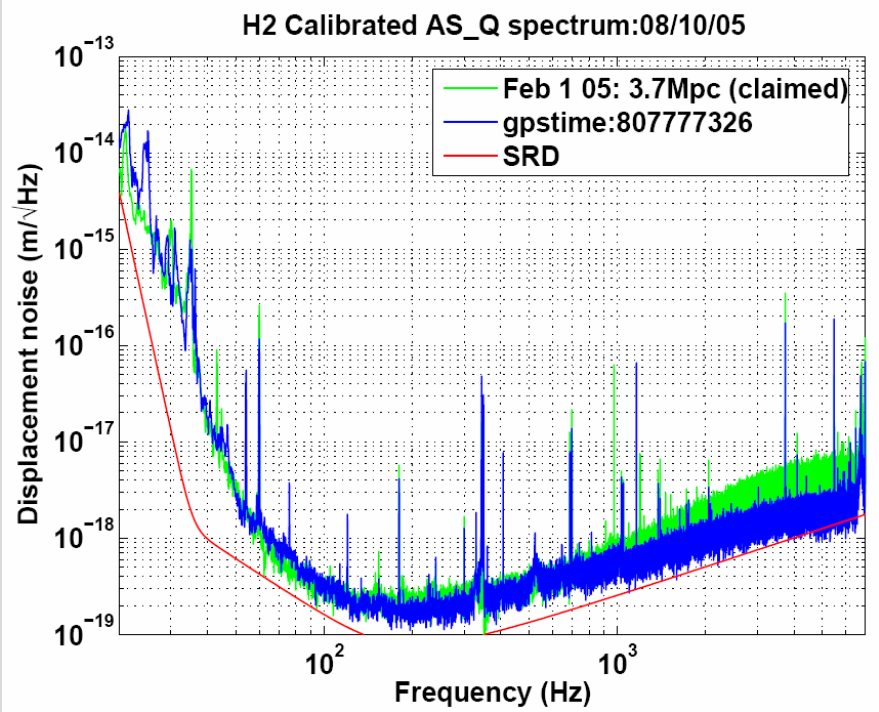
Scattered light fringe wrapping



- Data looks a lot like what you'd expect from scattered light
- Don't know where light is scattering off
- Beam tube baffles were made for this purpose: 270 mm aperture
  - Not currently installed in the beam (laid down in beam tubes)
  - Considering the possibility of erecting ETM baffles, to begin with in one IFO

H2: progress since S4

- 4-4.5 Mpc inspiral range
- Higher power
  - 1.5 W ⇨ 3 Watts
- Higher bandwidth WFS servos
  - Also for the mode cleaner WFS
- Low-noise crystal oscillator & RF distribution
- Thermal compensation at higher power
  - Servos implemented for TCS powers
  - Annulus heating (200mW on ITMY) required to maximize optical gain
- Code upgrade
  - LSC/ASC/DSC code now use double precision throughout
  - Done for all IFOs



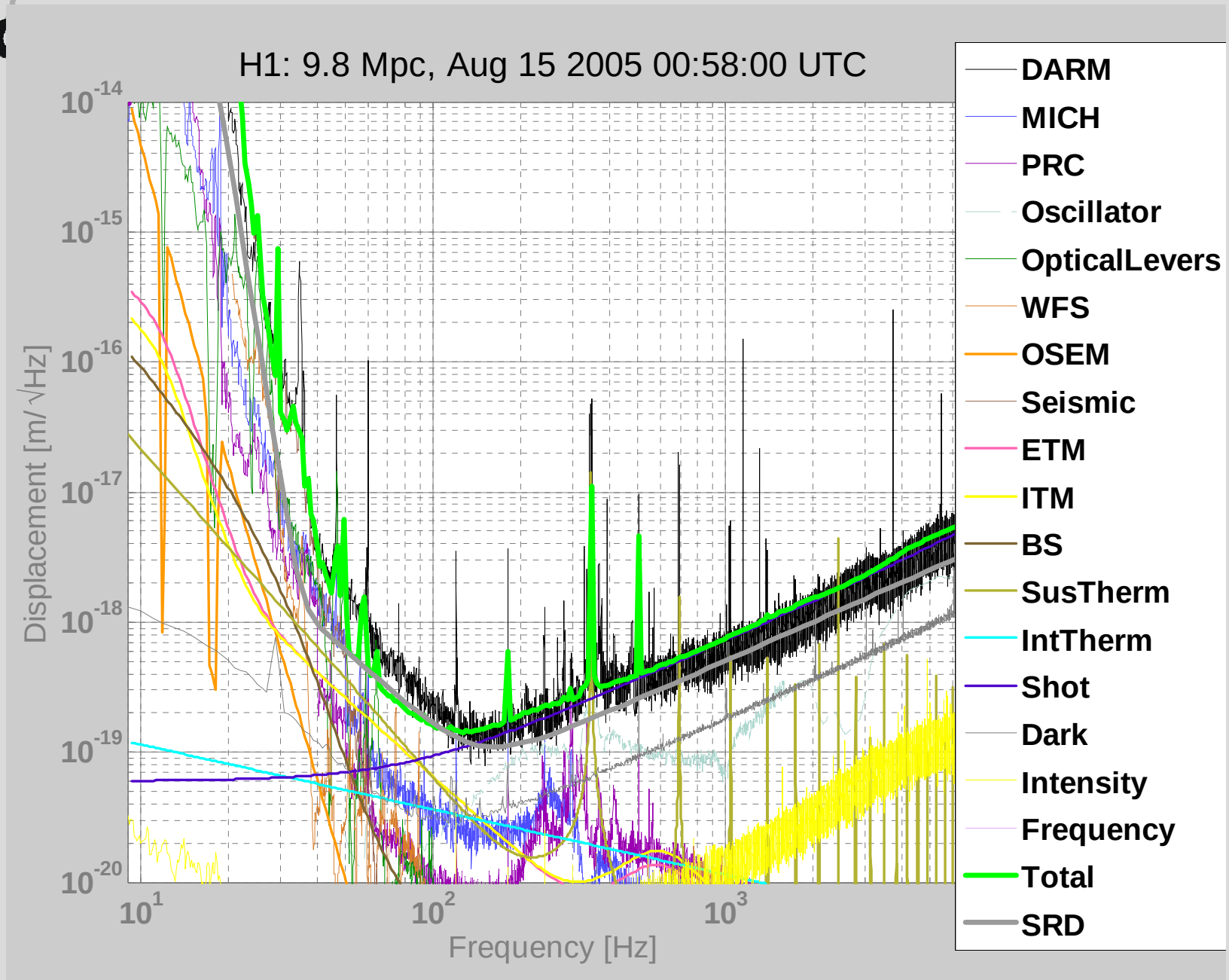
Note: The SRD curve (for the 4km), scaled properly for the 2km IFO, gives an inspiral range of 8.8 Mpc (vs. 14 Mpc for the 4k)

Now till S5

- REFL port beam pointing stabilization
  - L1, H1: heating distortion in the Faraday causes the REFL port beam to drift with power
  - Slow servo to stabilize position on REFL table to be implemented in September
- H2 laser replacement soon
- Timing system upgrade: to be installed on H2
- New acoustic enclosures for H1 and H2 REFL tables
  - Cut down on H1-H2 correlated noise
- H2: test of floating the AS port detection table
- Frequency noise reduction
  - Second detector at REFL port that (in principle) has a better SNR for frequency noise (more power, different modulation freq)
- AS port dust covers for L1
- Bias module fixes for LHO
- Frequency multiplier for crystal oscillator, LHO

During S5

- S5 will not be completely ‘hands-off’
- Expect to take 1-2 week breaks (every few months?) to try improvements
- For example:
  - Beam tube baffles
  - Power increase steps: new PMC, new laser
  - Propagate timing system upgrade


H1: 9.8 Mpc, Aug 15 2005 00:58:00 UTC
Displacement [m/√Hz]
Frequency [Hz]
DARM
MICH
PRC
Oscillator
OpticalLevers
WFS
OSEM
Seismic
ETM
ITM
BS
SusTherm
IntTherm
Shot
Dark
Intensity
Frequency
Total
SRD