LIGO Commissioning Update

LIGO Collaboration Meeting, Mar 18, 2003

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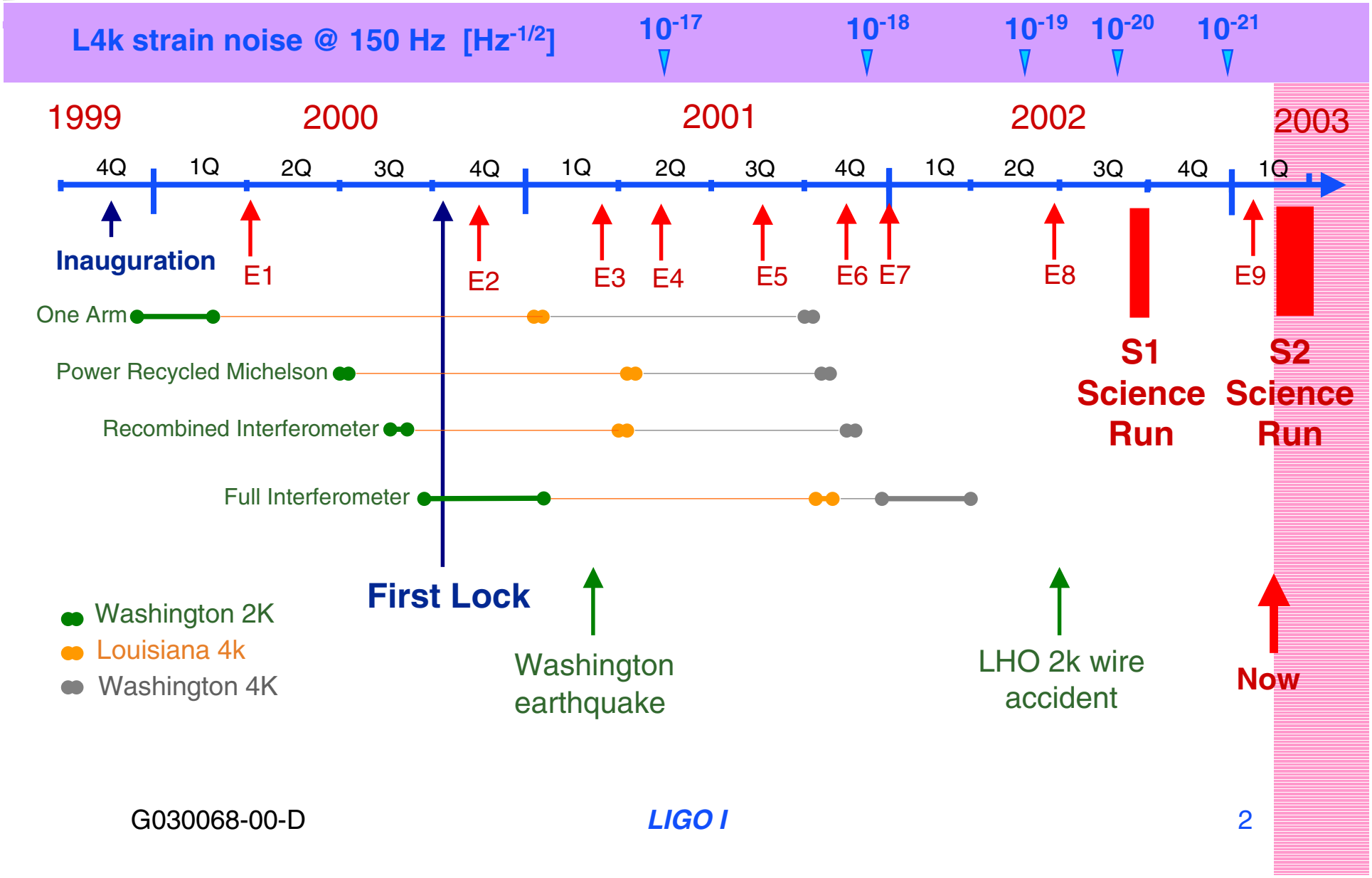
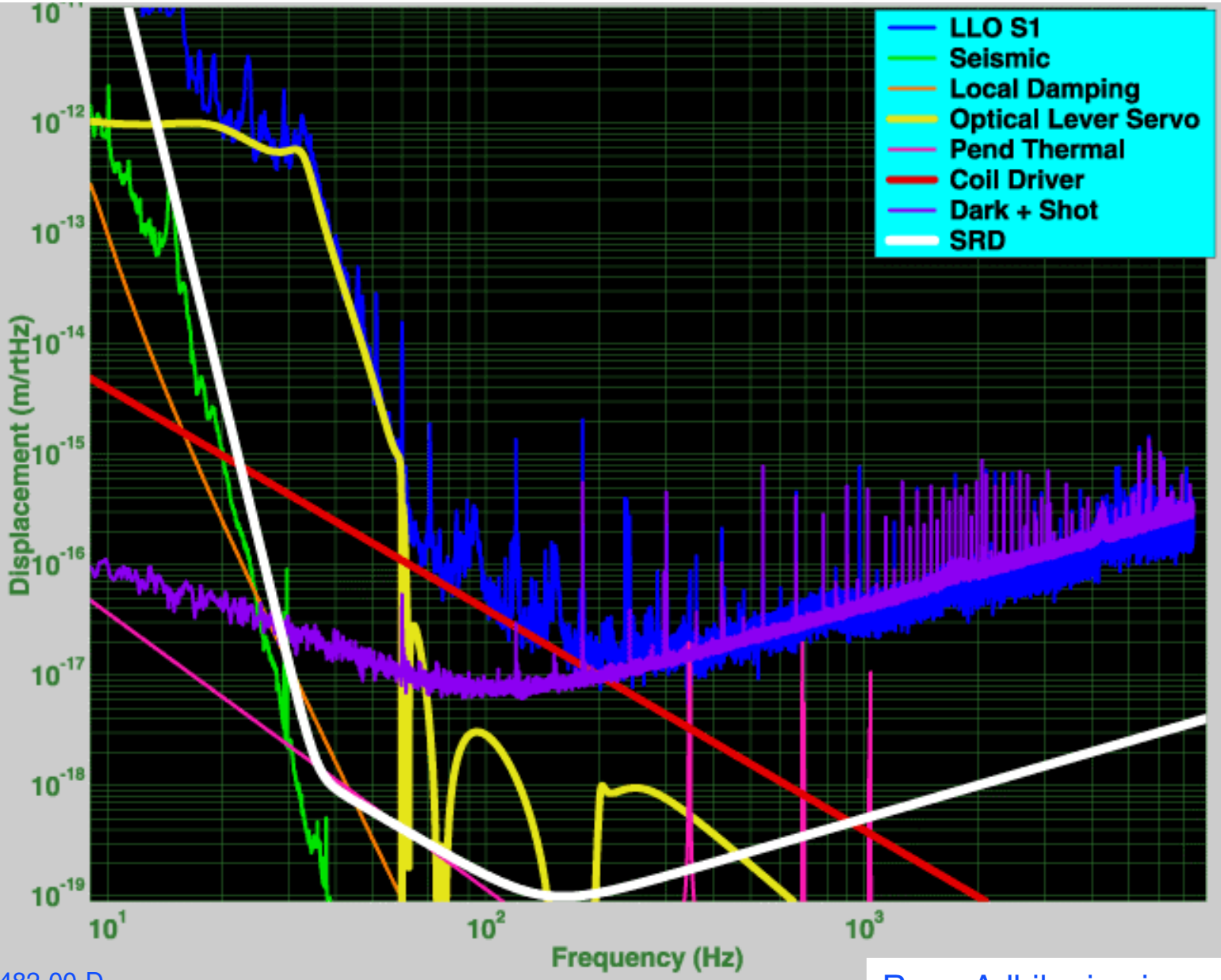
G030068-00-D

Commissioning History



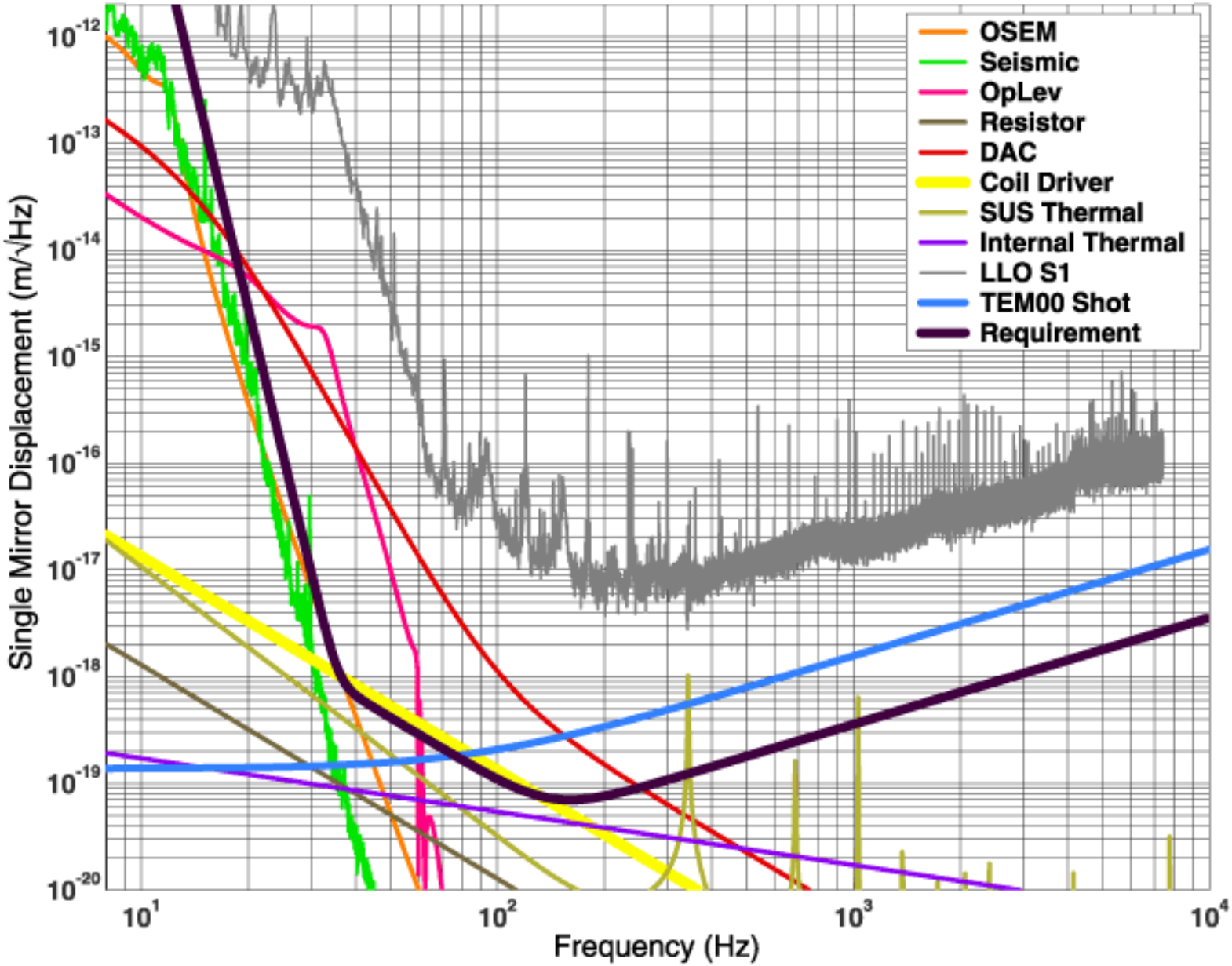
S1 Noise Component Analysis, LLO 4k



G020482-00-D

Rana Adhikari noise analysis

"Estimated Noise Limits for S2" (as foretold in October 2002)



Changes Since S1 (highlights)

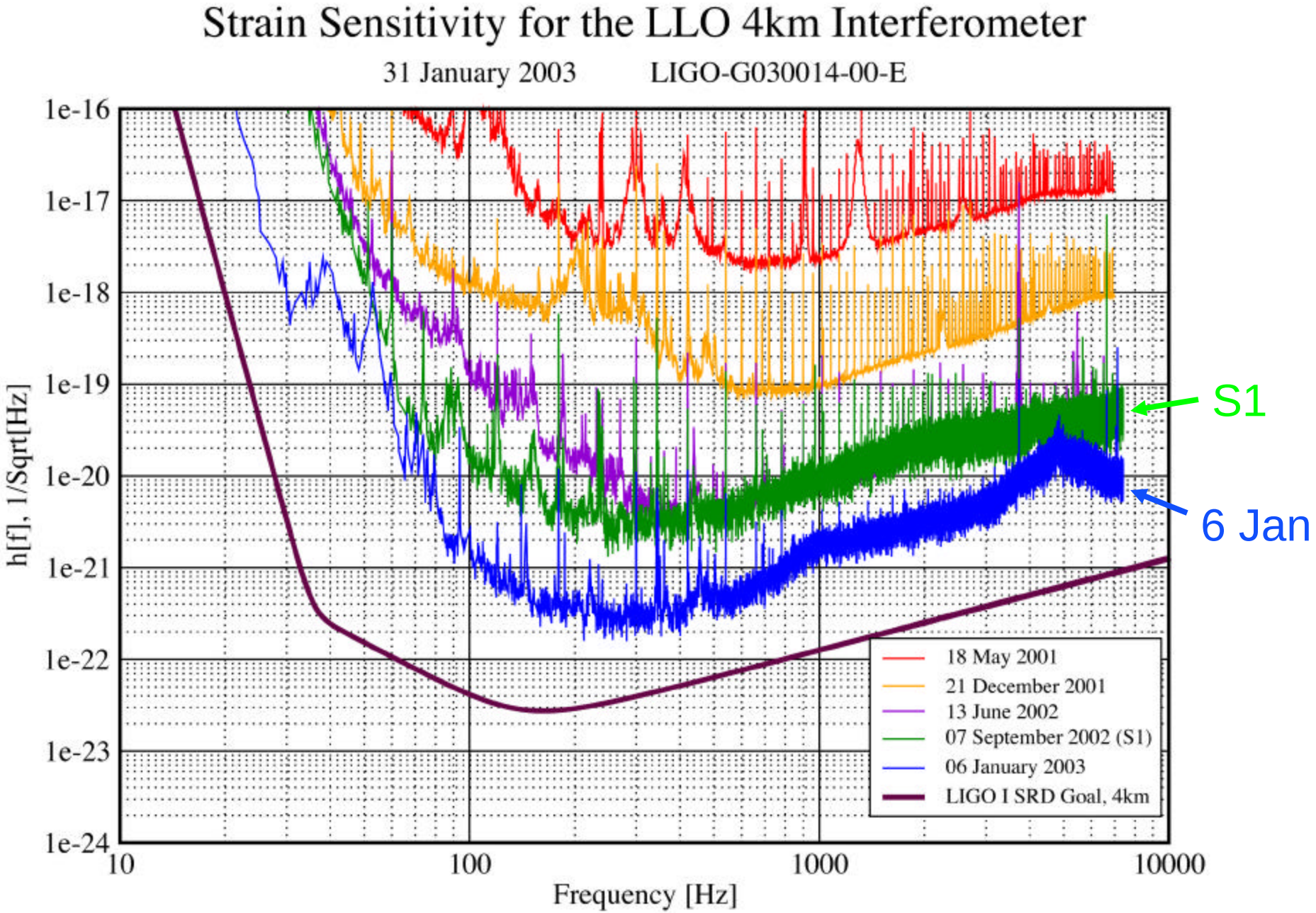
- Optical lever improvements
  - Structural stiffening (designed for thermal/kinematic stability, not low vibration)
  - Improved filtering to take advantage of reduced resonances
  - Pre-ADC "whitening" for improved dynamic reserve
- Improved DAC "De-Whitening"
  - Match DAC dynamic range to spectrum of correction forces at each frequency
  - Tricky handoff; reciprocal analog & digital filters must switch roles after lock acquisition, without transients
- New coil drivers & realtime control code for suspensions
  - Lower noise, switchable dynamic range (200 mA acquisition, 5 mA running)
  - Separate DC biases for alignment
  - Better filtering, diagonalization and control/sequencing features
- MORE POWER
  - Enabled by better alignment stability
  - Also required control of "I-phase" photocurrent (overload)
  - Now ~ 1.5 W into mode cleaners, ~ 40 W at beamsplitter (R~40)
  - Only 10-20 mA average DC photocurrent at dark ports !! (optics very good)

Stability improvements

- Wavefront sensing alignment control progress
  - H1: 8 of 10 (14) alignment degrees-of-freedom now under feedback control
    - Greatly improves long term power stability
    - Still need: all DOF; more feedback bandwidth to reduce short term power fluctuations
  - L1: Still 2 DOF under feedback control
    - Bandwidth of this loop increased 10x since S1, reducing short term fluctuations
    - Phase camera implemented: makes a 2-D map of the RF amplitude and phase
      - ✓ Proven useful as a manual alignment aid

Optical characterization

- Good news: optics quality is (almost all) good
  - Recycling gain meets or exceeds goals
    - L1: Gain of nearly 50 seen, more usually about 45
    - H1: Gain of 40-45
  - Contrast defect meets or exceeds goals
    - L1: $P_{as}/ P_{bs} = 3 \times 10^{-5}$
    - H1: $P_{as}/ P_{bs} = 6 \times 10^{-4}$
- Bad news: Very low RF sideband gain/efficiency
  - H1: Sideband power efficiency to AS port: ~6%
  - L1: similarly low
  - Cause: thermal lensing in the ITMs isn't at the design level
  - Achieving shot noise goal requires that this be fixed
- H2: Cause of low recycling gain (20) discovered
  - Bad (no) AR coating on ITMX, must be replaced


Strain Sensitivity for the LLO 4km Interferometer
31 January 2003
LIGO-G030014-00-E
h[f], 1/Sqrt[Hz]
1e-16
1e-17
1e-18
1e-19
1e-20
1e-21
1e-22
1e-23
1e-24
10
100
1000
10000
Frequency [Hz]
18 May 2001
21 December 2001
13 June 2002
07 September 2002 (S1)
06 January 2003
LIGO I SRD Goal, 4km
S1
6 Jan

Tasks at Hand

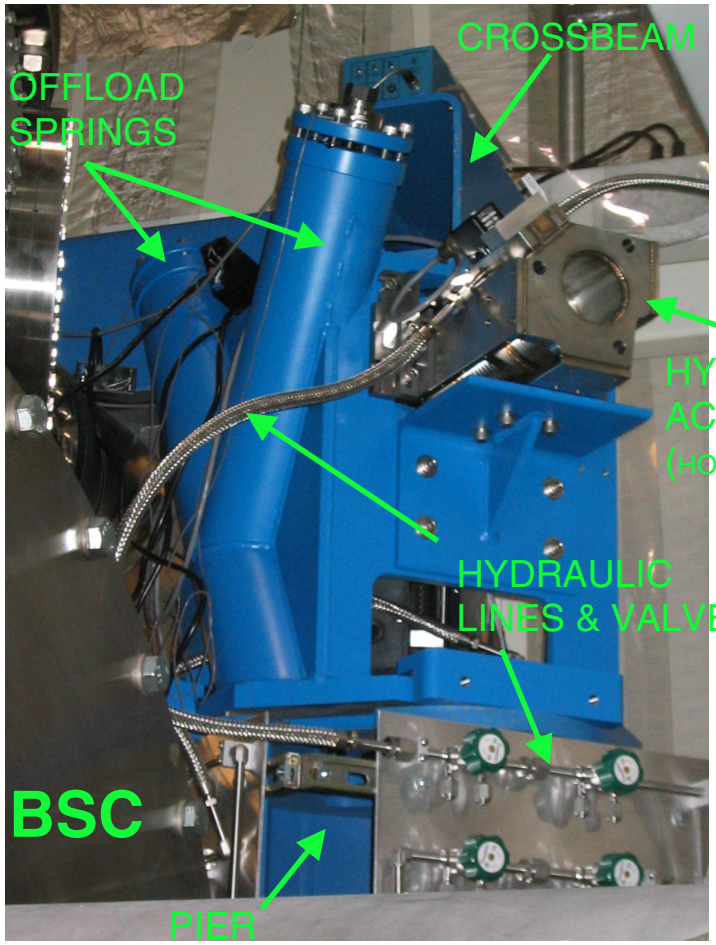
- Seismic retrofit at LLO
- Finish auto-alignment system
- RFI cleanup, linear power supplies
- Thermal lensing
- Optical gain increase of LSC photodiodes
- Shot noise sensitivity
- Acoustic coupling
- Others: microseismic peak reduction (LHO), ISS, photon calibrator, ASI servo, WFS 5, replace lossy PMCs, clean MC mirrors, digital IO WFS, tune up PSLs, remote power dial, 2K ITMX replacement, read/process more LSC channels, finish ν stabilization servos, duty cycle

Commissioning: SEI Upgrade

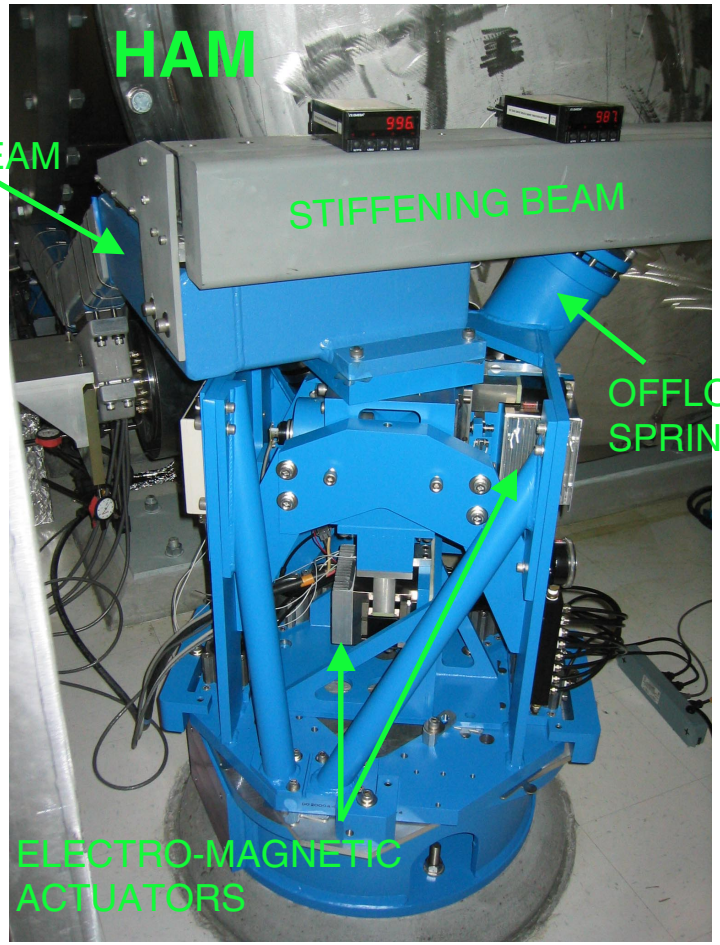
- The Seismic Isolation System (SEI) at LLO needs to be upgraded
  - To mitigate the higher seismic noise environment (logging principally)
  - Plan is to add an active, external pre-isolation (EPI) stage without disturbing the alignment of the installed optics
- Current Plan:
  - Continue prototype testing at LASTI, including migrating from dSpace to VME based controls
  - Order components, fabricate and assemble after successful review (planned for ~4/18); fabrication/assembly phase lasts ~5.5 months
  - Installation starts ~Oct and should complete ~Jan 2004
  - This frees up the piezoelectric, 2 DOF EPI systems at LLO for possible subsequent installation at LHO to help with high winds

Commissioning: SEI Upgrade

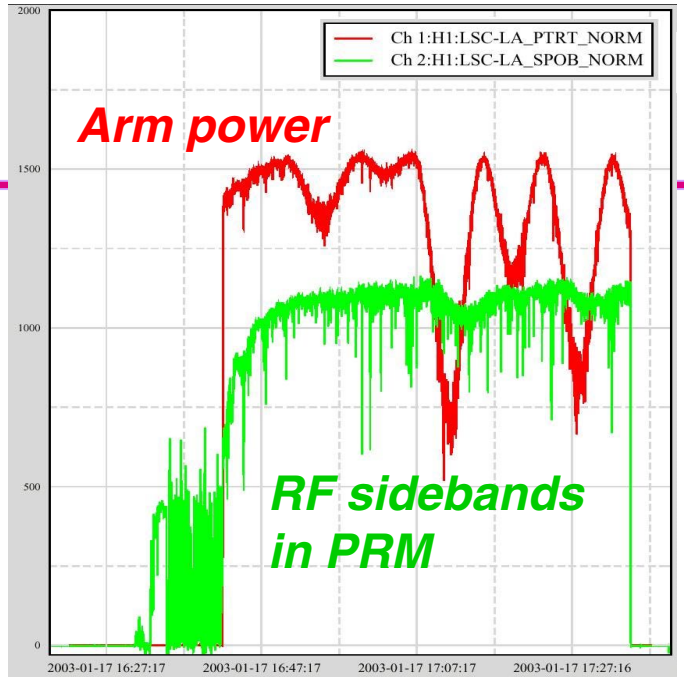
Hydraulic External Pre-Isolator (HEPI)



electro-Magnetic External Pre-Isolator (MEPI)



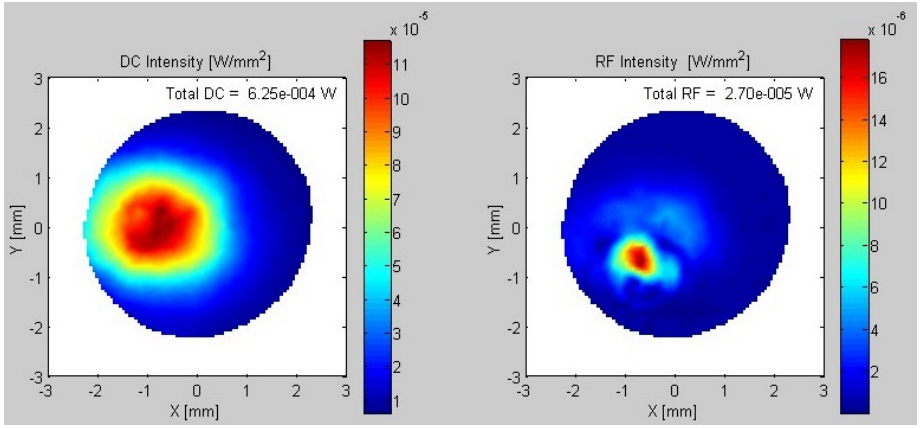
Thermal Lensing



ITM Heating

- RF sideband efficiency is very low
  - Efficiency: TEM_{00} SB power at anti-symmetric port, relative to input SB power
  - H1 efficiency: ~6%
  - Need a stable PRM: lack of ITM thermal lens makes $g_1 \cdot g_2 > 1$
  - Currently see some lensing in H1
- Possible solutions
  - Change RM (w/ new ROC); 6 month lead time
  - Add the missing heat to ITMs with another source
  - 20-25 W PSL with additional LWE amplifier

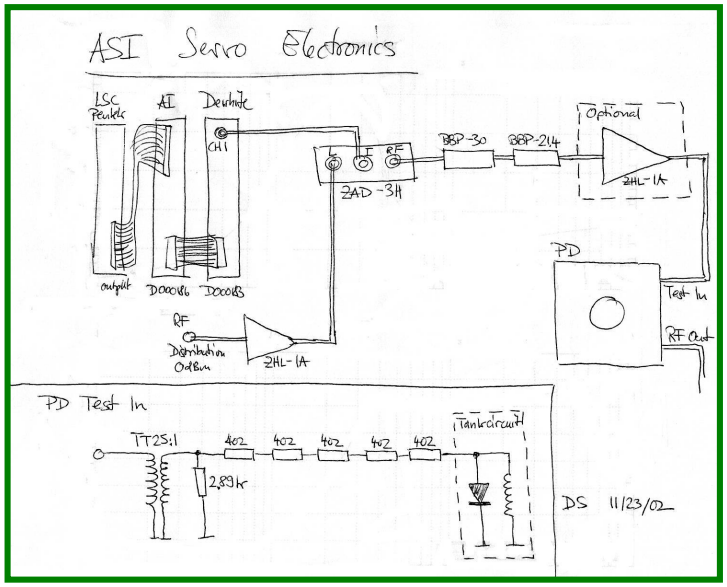
Bad mode overlap



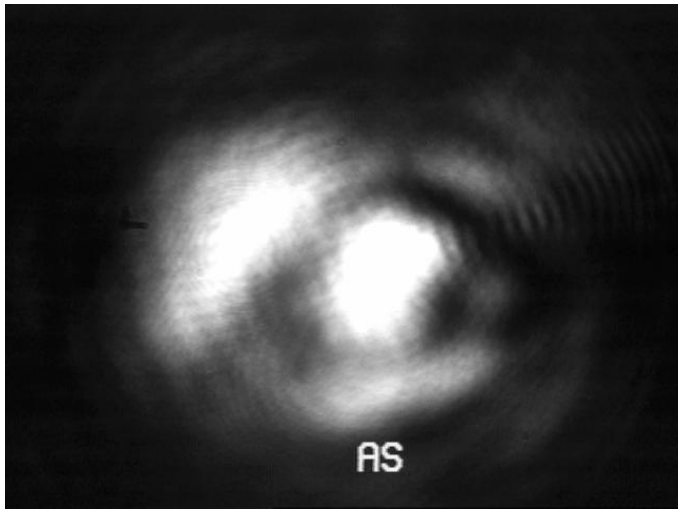
DC (carrier) ***RF sidebands***

Optical Gain Increase for LSC Photodiodes

- Dynamic range problem: 1000x
  - Locking ~100 μA / running ~100 mA
  - EO shutter range: 200-700
  - Solutions:
    - Two EO shutters running in series
    - Separate PDs for locking (low power) and running (high power)
    - Remote dial for laser power



ASI Servo

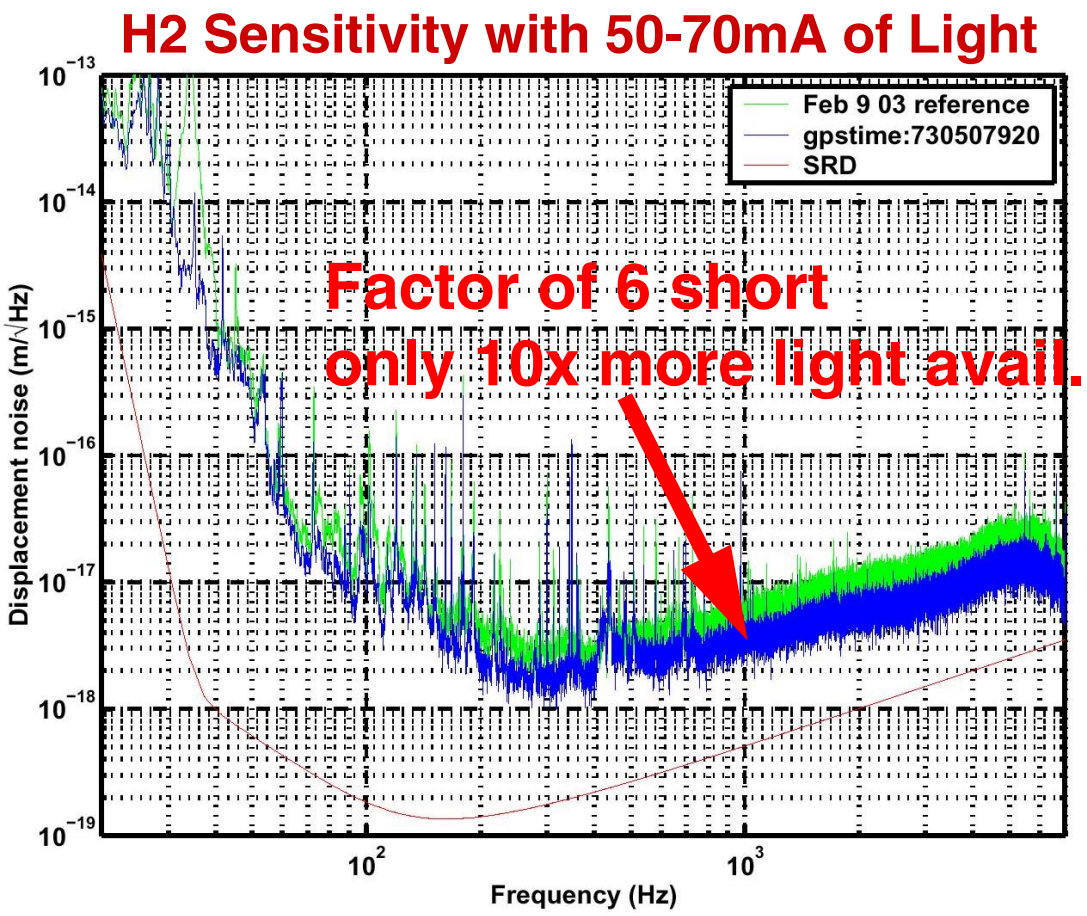


AS Port

- ASI signal dominant!
- Multiple AS port detectors
  - H1: P_{AS} = 500-600 mW ⇨ 4 detectors
  - L1: P_{AS} = ~20-30 mW ⇨ 1 detector

Shot Noise Sensitivity

- AS port: project a factor of ~2 shortfall
  - Reasonable SB efficiency with thermal lensing will get us there
  - Output mode cleaner for AS would also get factor of ~2, may also be desirable to eliminate scattered/junk light
- Pick-off detector



Acoustic Peaks: Scattering/Clipping

- Peaks occur in 80-1000 Hz band, at a level 10-100x the SRD
- Source for H1/H2 coincidences(?)
- Should consider:
  - Active ISCT beam direction stabilization
  - Acoustic isolation improvements: ISC tables only, or all LVEA?
  - Modify output periscopes/mirror mounts: stiffer, damped
  - Mount Faraday isolators onto ISC tables
  - Larger in-vacuum Faraday, larger EO shutters
  - In-vacuum, seismically isolated output bench

Acoustic Excitations