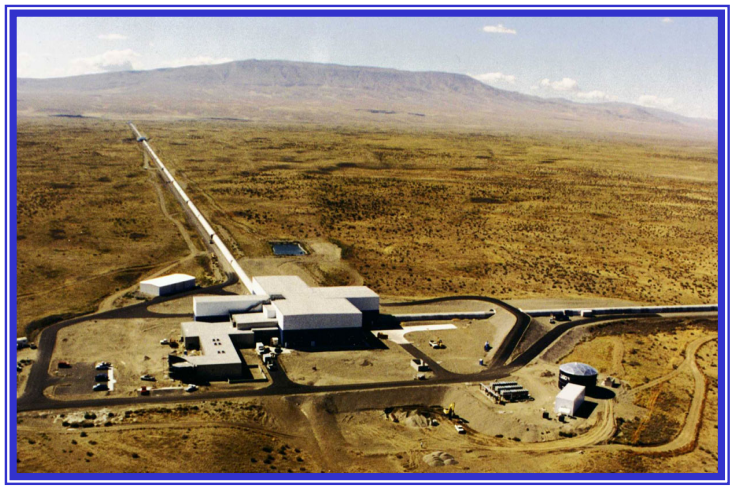
Commissioning and Detector Plans

Stan Whitcomb



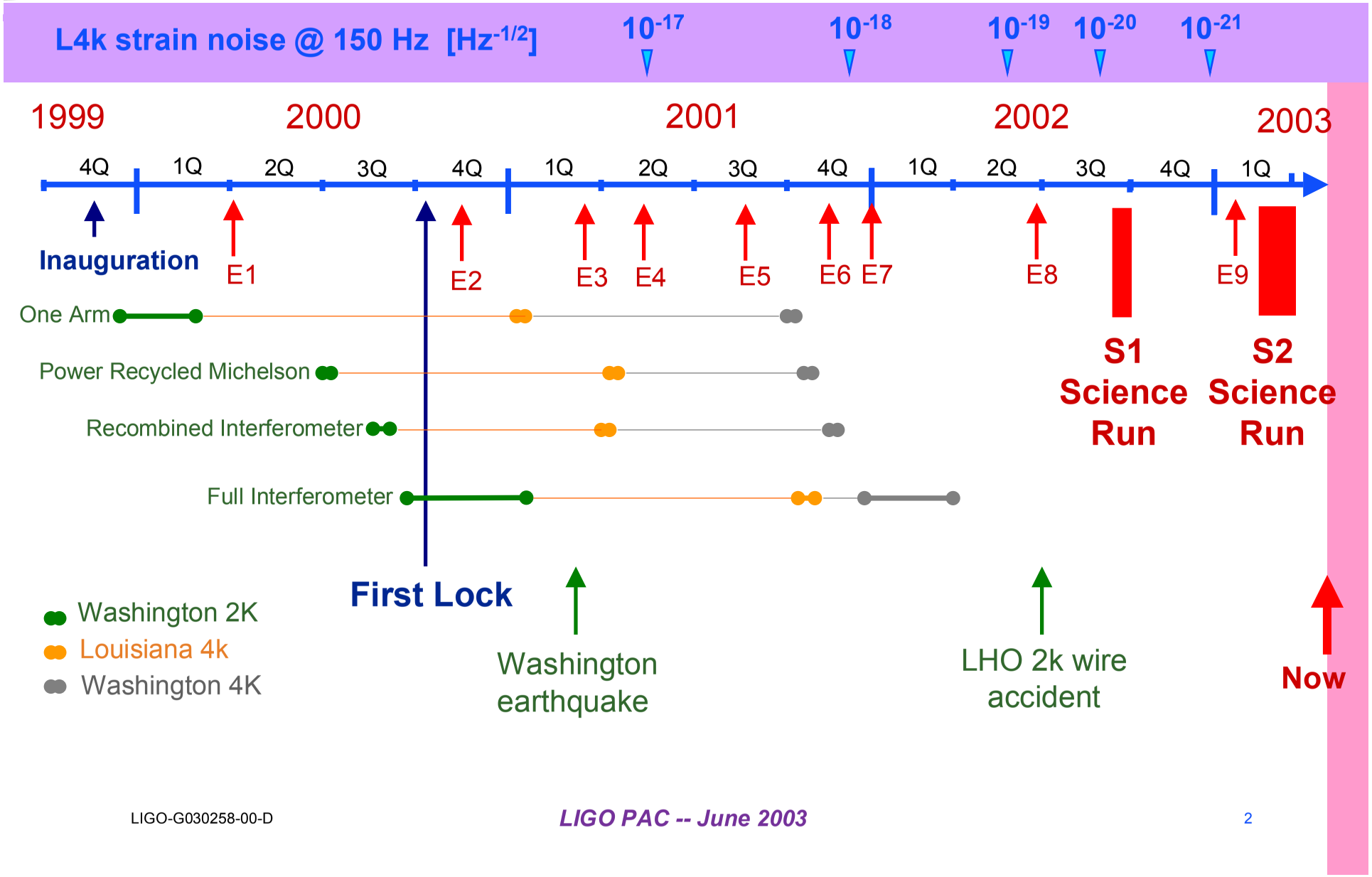
Program Advisory Committee

6 June 2003

Caltech

LIGO-G030258-00-D

Commissioning History

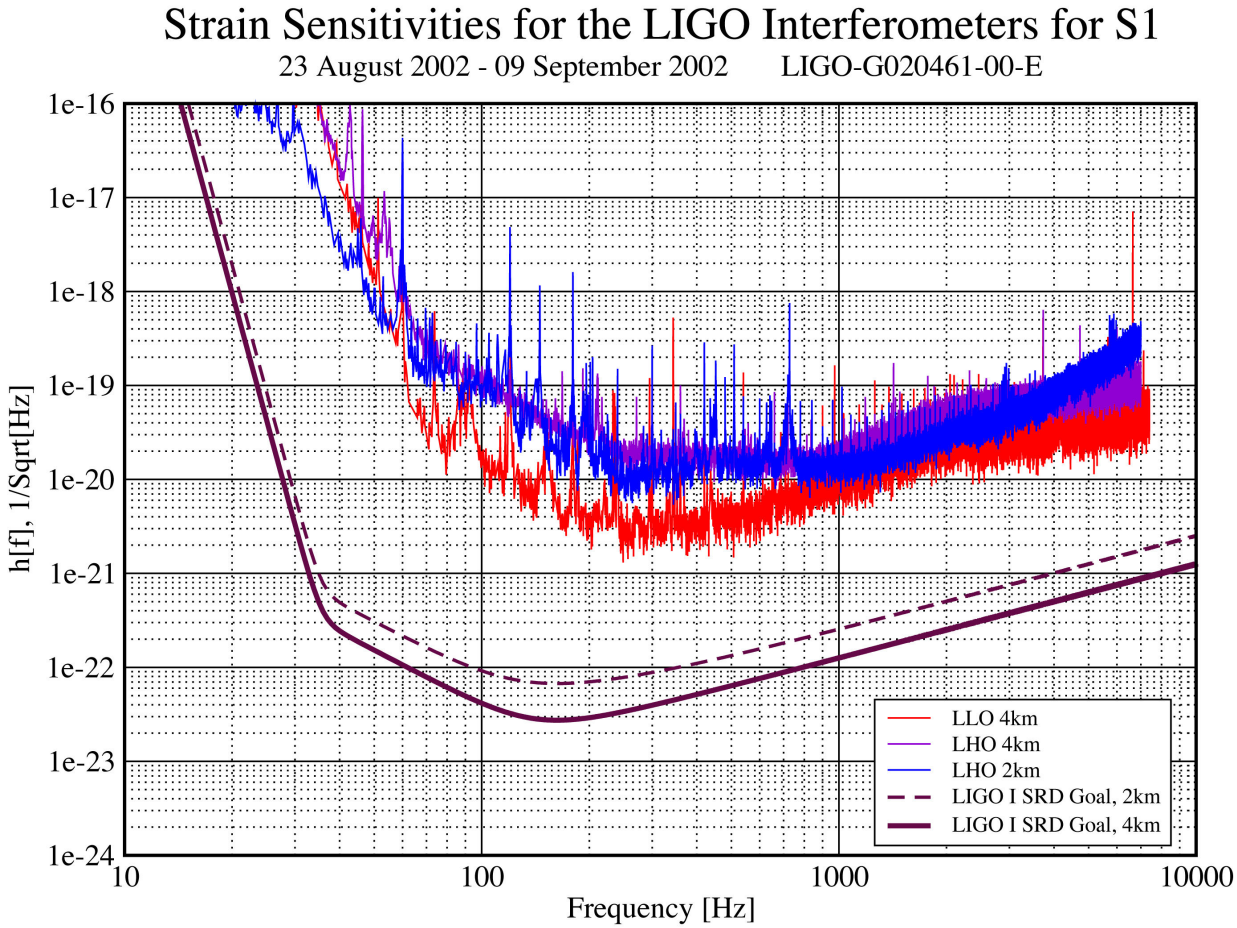


First Science Run (S1)

- August 23 - September 9, 2002 (~400 hours)
- Three LIGO interferometers, plus GEO (Europe) and TAMA (Japan)
- Range for binary neutron star inspiral ~ 40-200 kpc
- Hardware reliability good for this stage in the commissioning
  - » Longest locked section for individual interferometer: 21 hrs (11 in “Science mode”)

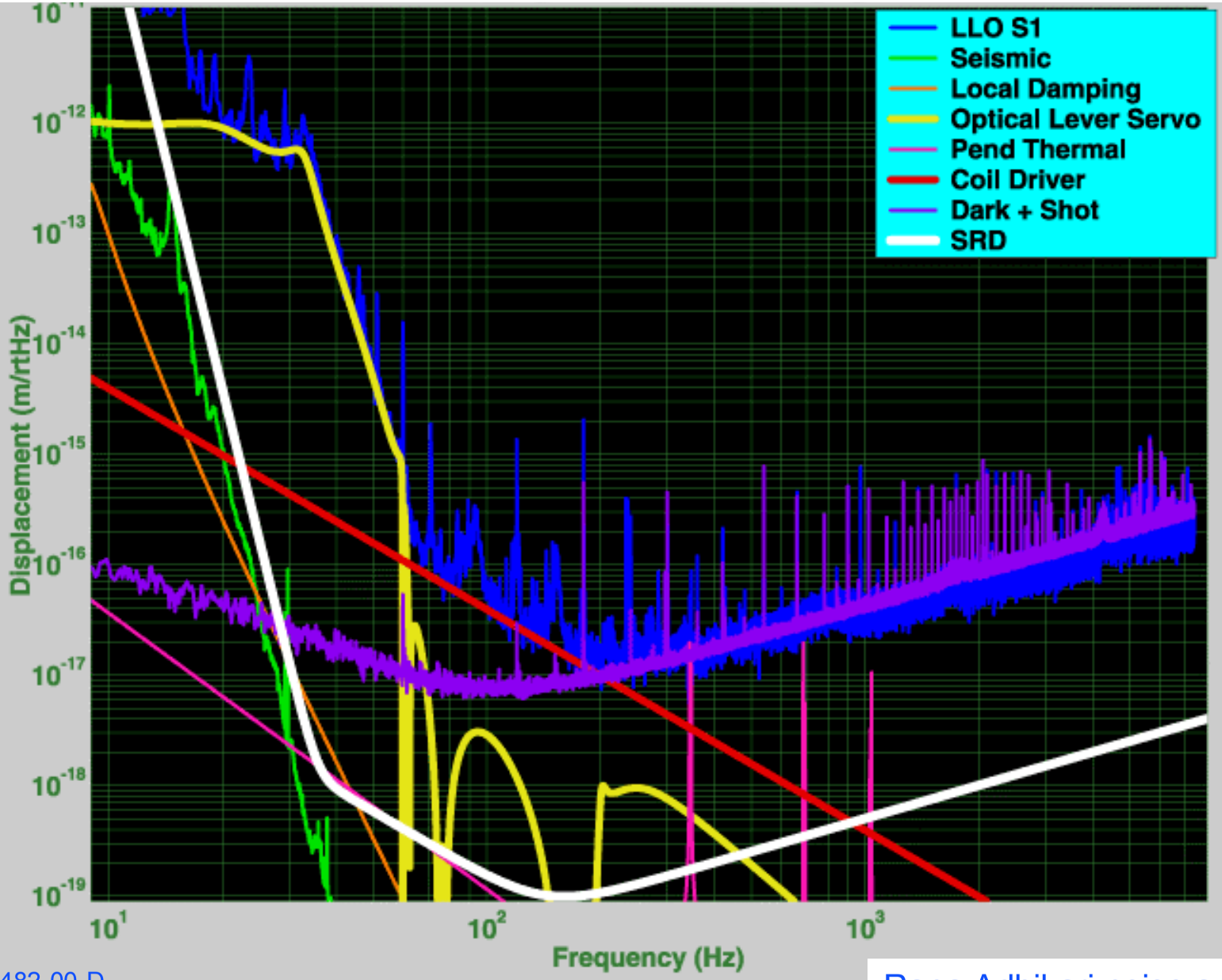
	LLO-4K	LHO-4K	LHO-2K	3x Coinc.
Duty cycle	42%	58%	73%	24%

S1 Sensitivities



Will hear about searches for different sources tomorrow

S1 Noise Component Analysis, LLO 4k



G020482-00-D

Rana Adhikari noise analysis

Changes Between S1 and S2

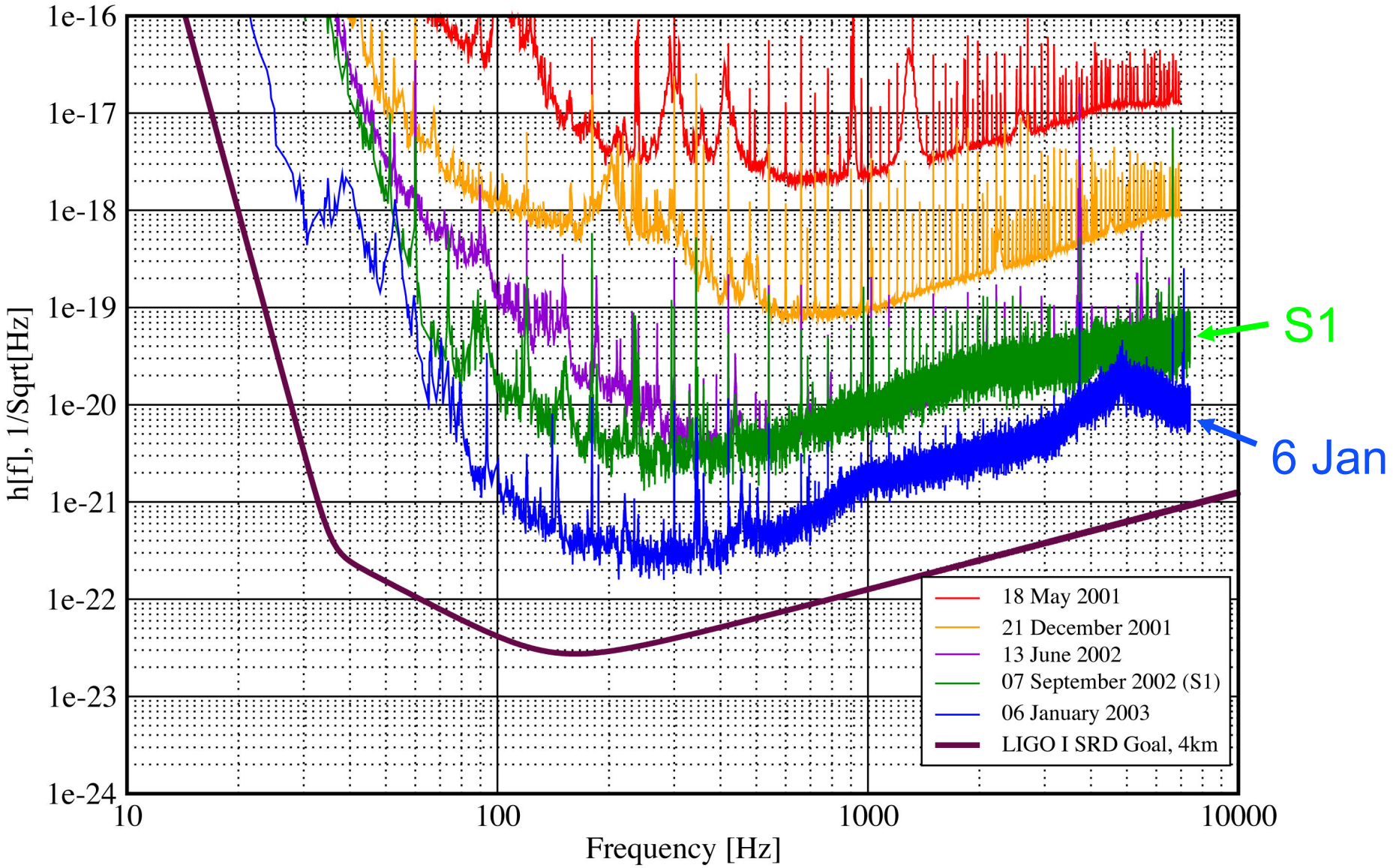
- Optical lever improvements
  - » Structural stiffening (designed for thermal/kinematic stability, not low vibration)
  - » Improved filtering to take advantage of reduced resonances
  - » Pre-ADC "whitening" for improved dynamic reserve
- Improved DAC "De-Whitening"
  - » Match DAC dynamic range to spectrum of correction forces at each frequency
  - » Tricky handoff; reciprocal analog & digital filters must switch roles after lock acquisition, without transients
- Digital Suspensions installed on LHO-2K and LLO-4K
  - » 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 for S2

- Wavefront sensing alignment control progress
  - » LHO-4K: 8 of 10 (14) alignment degrees-of-freedom under feedback control
    - – Greatly improves long term power stability
    - – Still need: all DOF; more feedback bandwidth to reduce short term power fluctuations
  - » LLO-4K: 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
  - » LHO-4K: 2 DOF under feedback control

Strain Sensitivity for the LLO 4km Interferometer

31 January 2003 LIGO-G030014-00-E

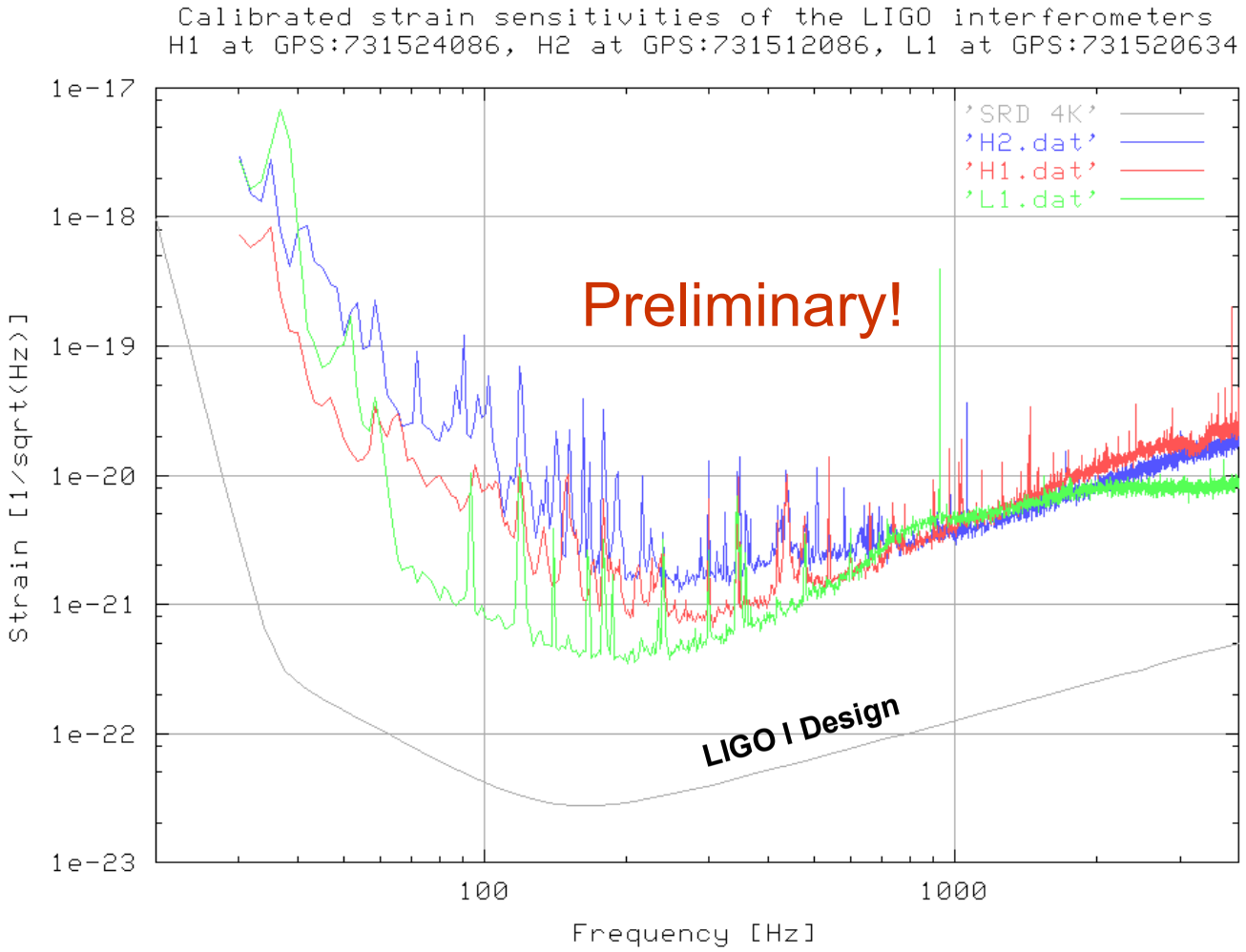


Second Science Run (S1)

- February 14 – April 14, 2002 (~ 1400 hours)
- Three LIGO interferometers and TAMA (Japan)
- Steady improvement in sensitivity continues
  - » Range for binary neutron star inspiral for LLO-4K up to 1.2 Mpc
- Duty cycle similar to S1
  - » Increased sensitivity did not degrade operation
  - » Longest locked stretch ~ 66 hours (LHO-4K)

	LLO-4K	LHO-4K	LHO-2K	3x Coinc.
Duty cycle	37% (42%)	74% (58%)	58% (73%)	22% (24%)

S2 Sensitivities



Approximately 10x improvement over S1

Tasks at Hand

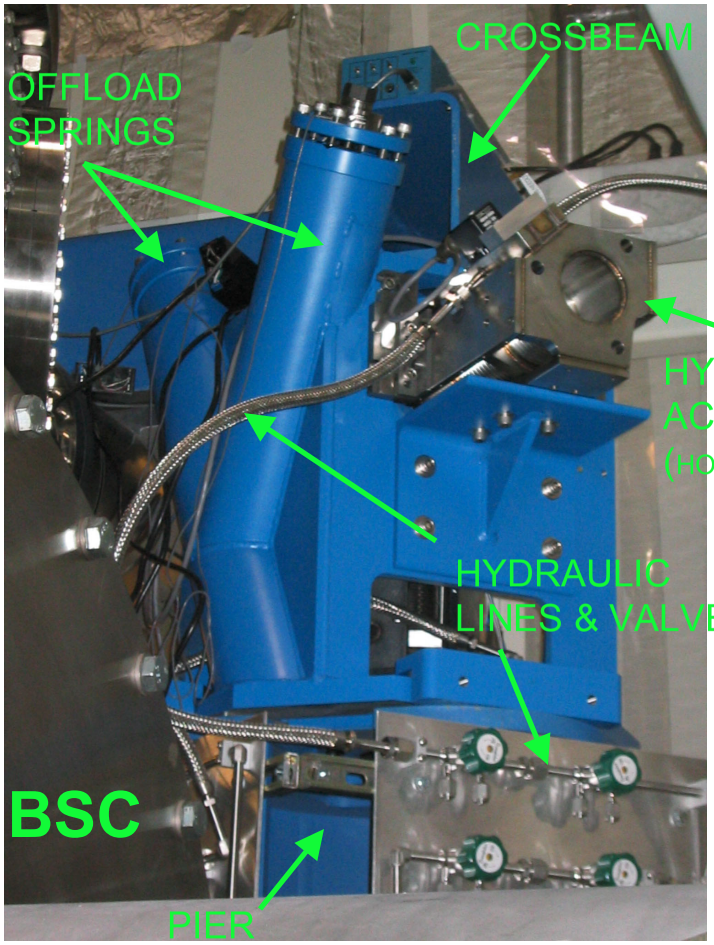
- Seismic retrofit at LLO
- Finish wavefront sensing alignment system
- RFI cleanup, linear power supplies
- Thermal lensing
- Shot noise sensitivity
- Optical gain increase of LSC photodiodes
- Acoustic coupling
- Others: microseismic peak reduction (LHO), ISS, photon calibrator, ASI servo, WFS 5, replace 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

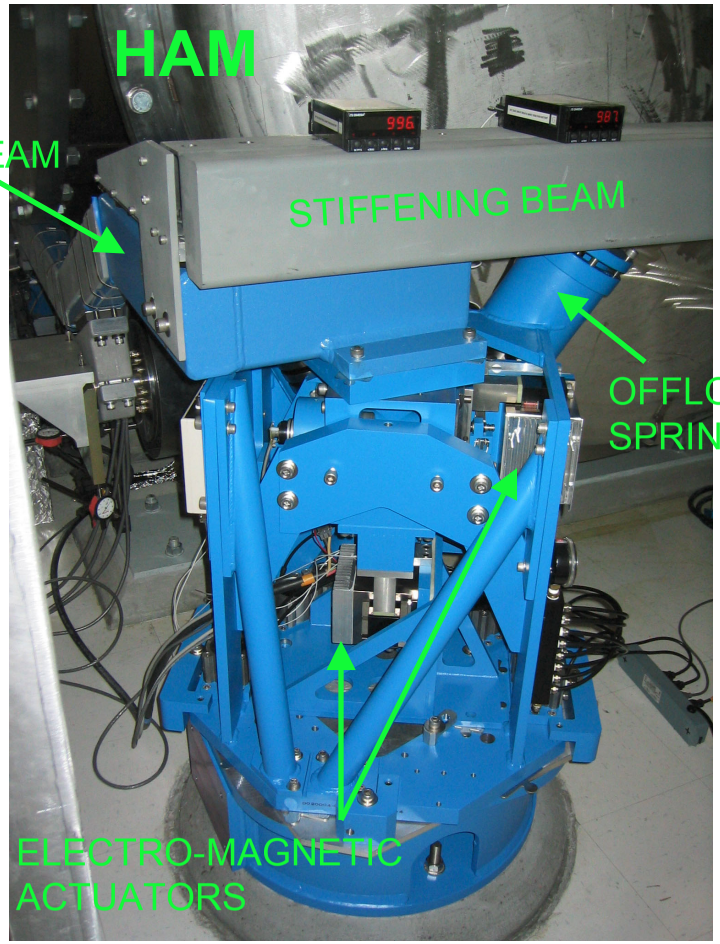
- The Seismic Isolation System (SEI) at LLO needs to be upgraded
  - » Seismic noise environment much worse below 10 Hz than originally planned (logging largest factor, but also train, other anthropogenic noise)
  - » Plan is to add an active, external pre-isolation (EPI) stage without disturbing the alignment of the installed optics
- Current Plan:
  - » Continue prototype testing at LASTI, including migrating from dSpace to VME based controls
  - » Review held for 4/18; management decision on how to proceed pending
  - » Order components, fabricate and assemble; fabrication/assembly phase lasts ~5.5 months
  - » Installation starts ~Jan ‘04 and should complete ~Apr ‘04

Commissioning: SEI Upgrade at MIT

Hydraulic External Pre-Isolator (HEPI)



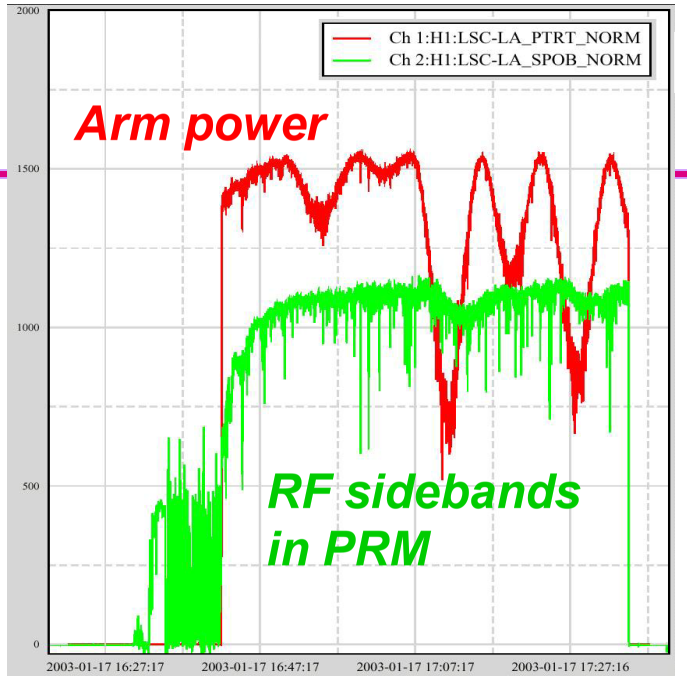
electro-Magnetic External Pre-Isolator (MEPI)



Optical characterization

- Good news: optics quality is (almost all) good
  - » Recycling gain meets or exceeds goals
    - – LLO-4K: Gain of nearly 50 seen, more usually about 45
    - – LHO-4K : Gain of 40-45
  - » Contrast defect meets or exceeds goals
    - – LLO-4K : $P_{as}/ P_{bs} = 3 \times 10^{-5}$
    - – LLO-4K : $P_{as}/ P_{bs} = 6 \times 10^{-4}$
- Bad news: Very low RF sideband gain/efficiency
  - » LHO-4K : Sideband power efficiency to AS port: ~6%
  - » Cause: thermal lensing in the ITMs isn't at the design level
  - » Achieving shot noise goal requires that this be fixed
- LHO-2K: Cause of low recycling gain (20) discovered
  - » Bad AR coating on ITMX, must be replaced

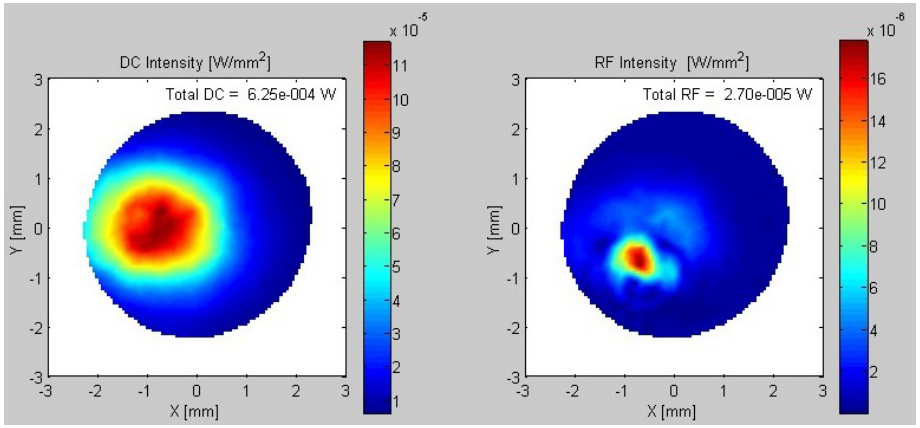
Thermal Lensing



- 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 $g_1 \cdot g_2 > 1$
  - » Thermal lensing relies on point design
- Possible solutions
  - » Change RM (w/ new ROC); 6 month lead time
  - » Add the missing heat to ITMs with another source
  - » Operate at optimal power (could be higher or lower than design!)

ITM Heating

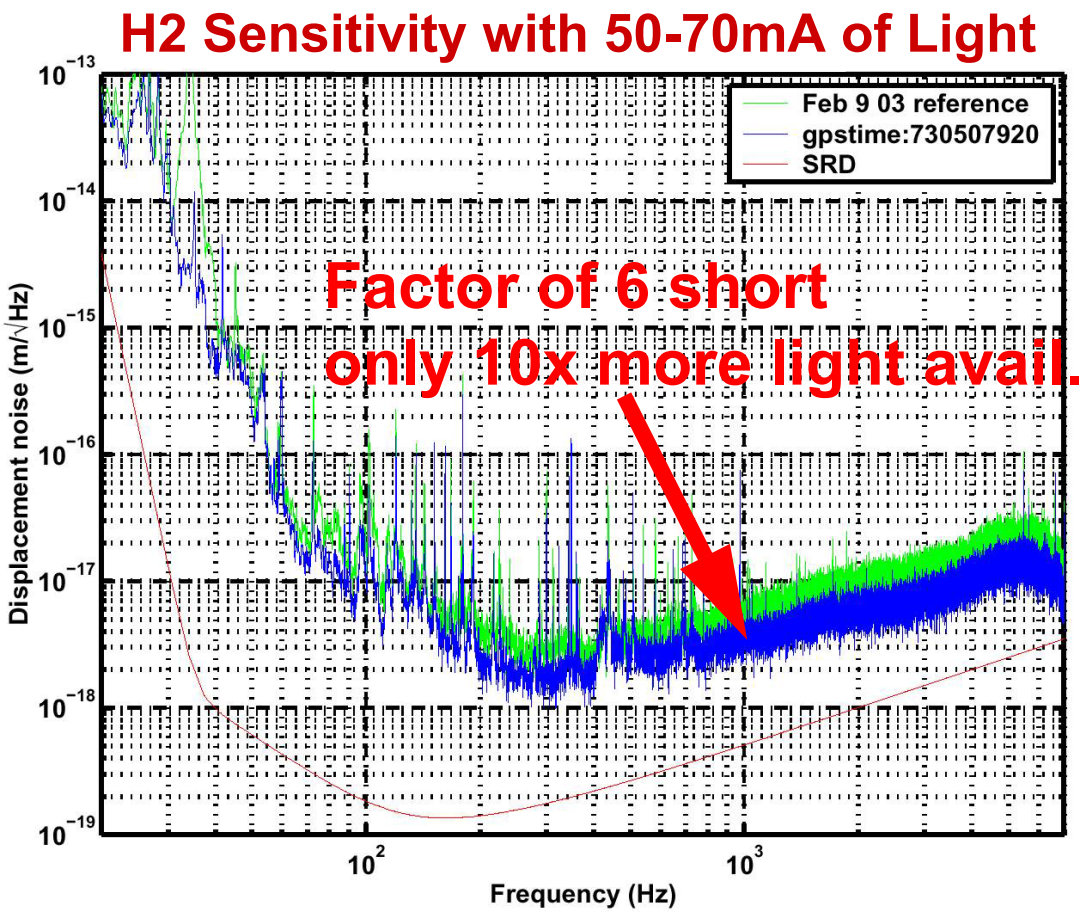
Bad mode overlap



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

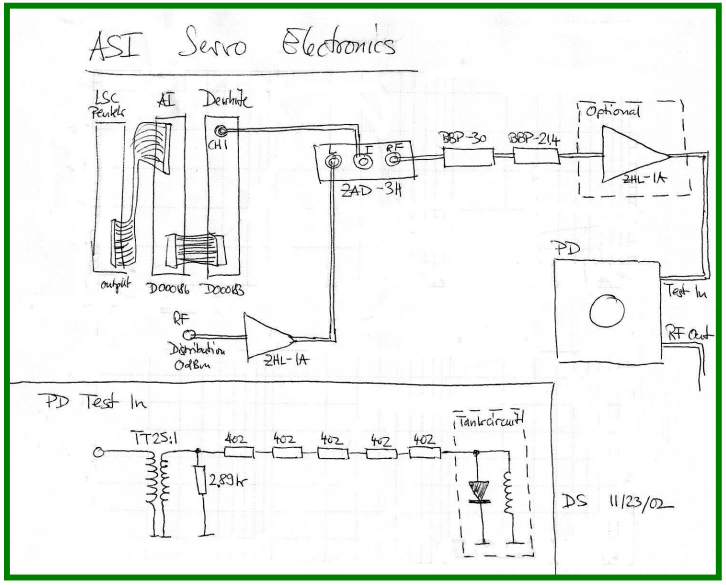
Shot Noise Sensitivity

- Simple power calculations project a factor of ~2 shortfall
  - » Improvements to SB efficiency with thermal lensing should get us there
- Pick-off detector
  - » Power levels in pick-off beams not well controlled, could limit noise through cross-couplings if not careful

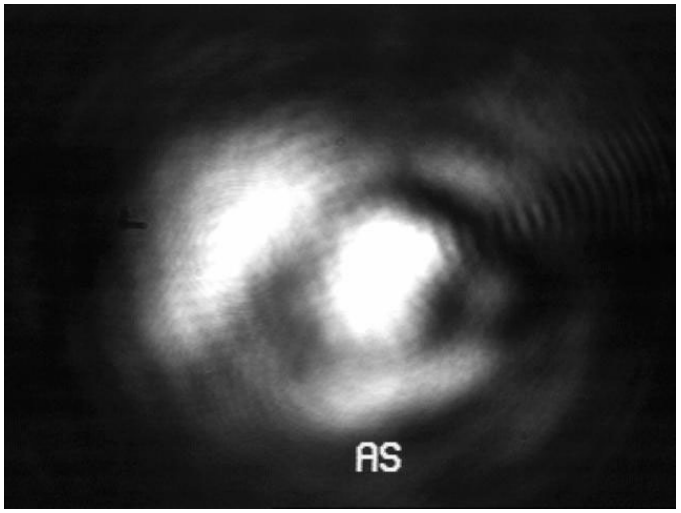


Optical Gain Increase for LSC Photodiodes

- Dynamic range requirement: 1000x
  - » Locking ~100 μA / running ~100 mA
  - » Solution:
    - – Separate PDs for locking (low power) and running (high power)
    - – Remote control for input power



ASI Servo



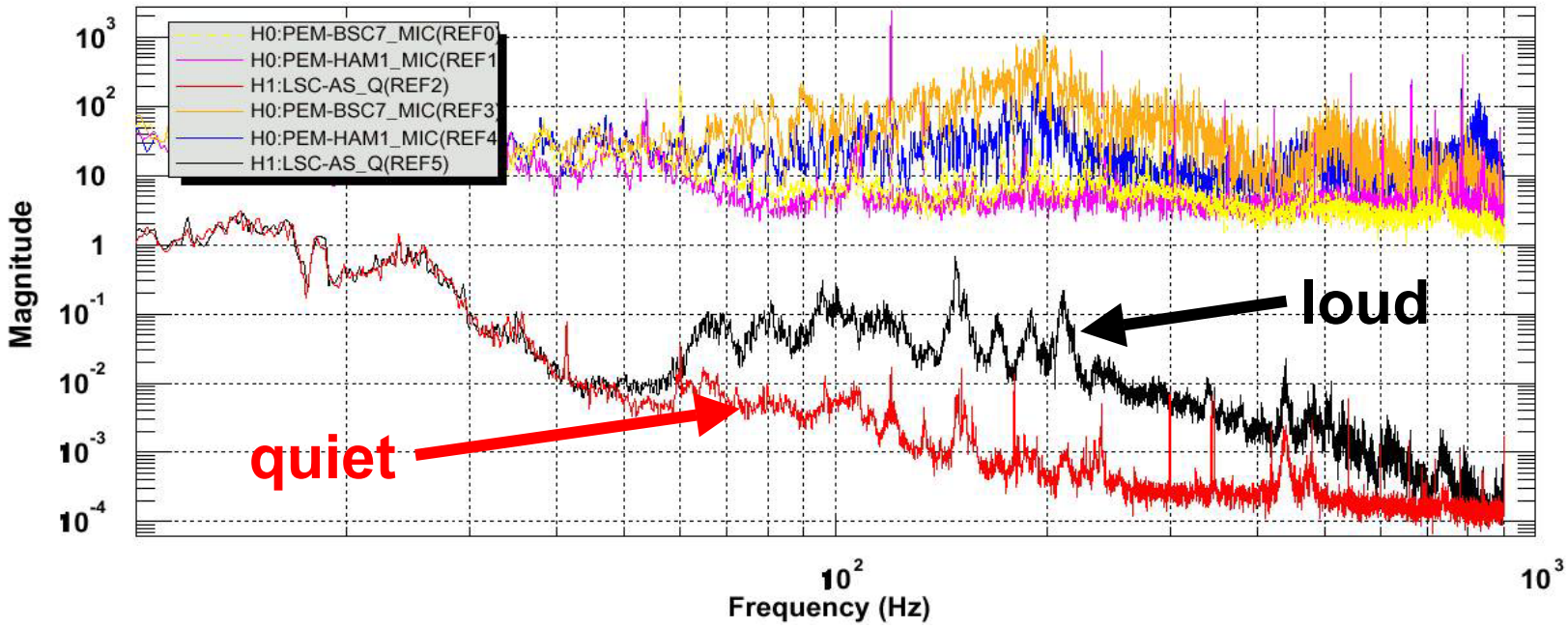
AS Port

- ASI signal dominant!
- Multiple AS port detectors
  - » LHO-4K: P_{AS} = ~500 mW ⇨ 4 detectors
  - » LLO-4K: P_{AS} = ~30 mW ⇨ 1 detector

Acoustic Peaks: Scattering/clipping

- Peaks occur in 80-1000 Hz band, at a level 10-100x the SRD
- Source for LHO correlated noise (stochastic search)
- Considering:
  - » Acoustic isolation improvements: ISC tables only, or all LVEA?
  - » Modify output periscopes/mirror mounts: stiffer, damped
  - » Active ISCT beam direction stabilization
  - » Larger in-vacuum Faraday
  - » Eliminate EO shutters

Acoustic Excitations



Summary

- Lots to do!