LIGO

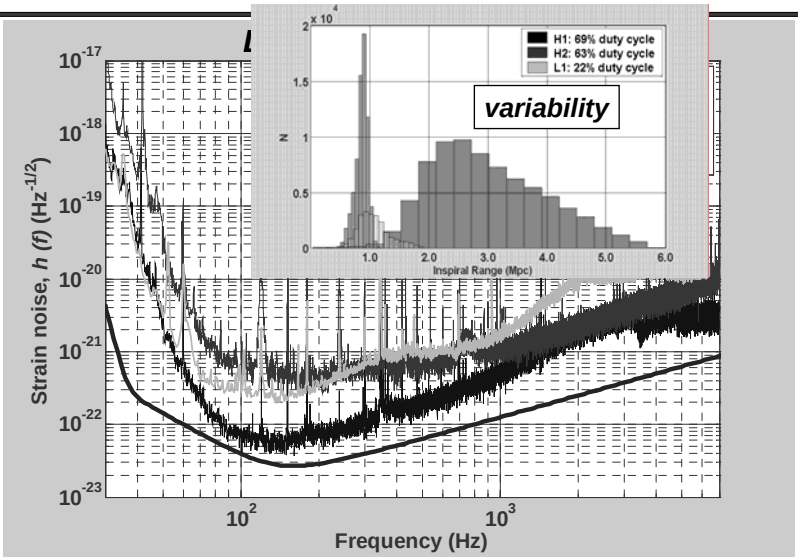
LIGO Commissioning

Peter Fritschel

PAC17, 2 Dec 2004

LIGO

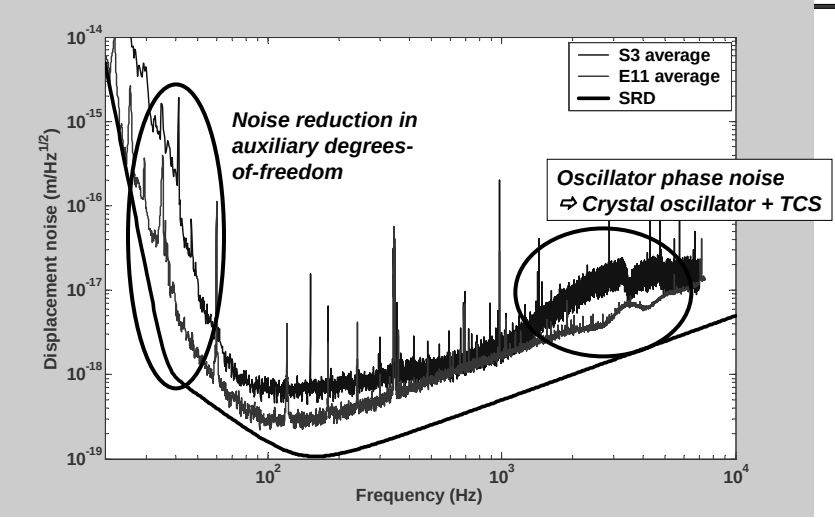
Reminder of S3 performance



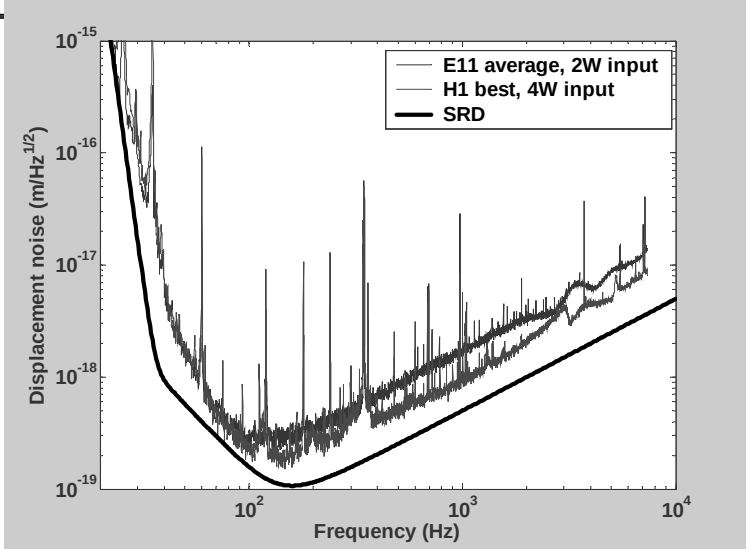
Post-S3 areas of focus

- **Sensitivity**
  - Increase laser power
  - Active thermal compensation
  - Phase noise of RF oscillator
  - Noise coupling from auxiliary degrees-of-freedom
  - Output mode cleaner tests
- **Reliability and stability**
  - Seismic retrofit at LLO
  - RFI retrofit at LLO
  - Improvements to auto-alignment system
  - Address causes of lock-loss

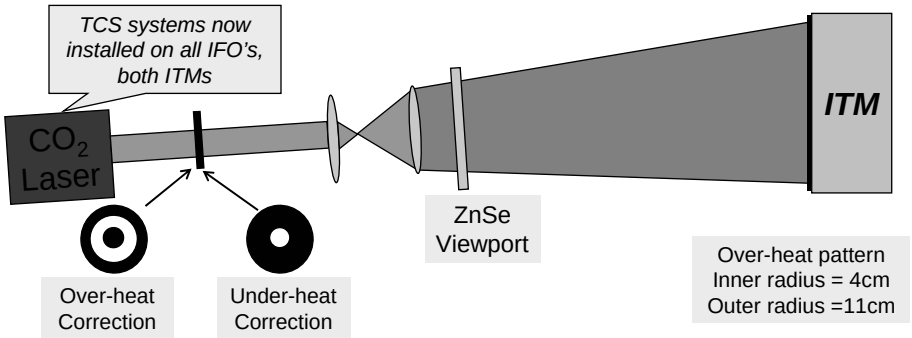
Noise improvement on H1



H1 goal for next science run



Thermal Compensation



- Cold power recycling cavity is unstable: poor buildup and mode shape for the RF sidebands
- ***ITM thermal lens*** power of ~0.00003 diopters needed to achieve a stable, mode-matched cavity
  - intended to be produced by ~30 mW absorbed from 1μm beam

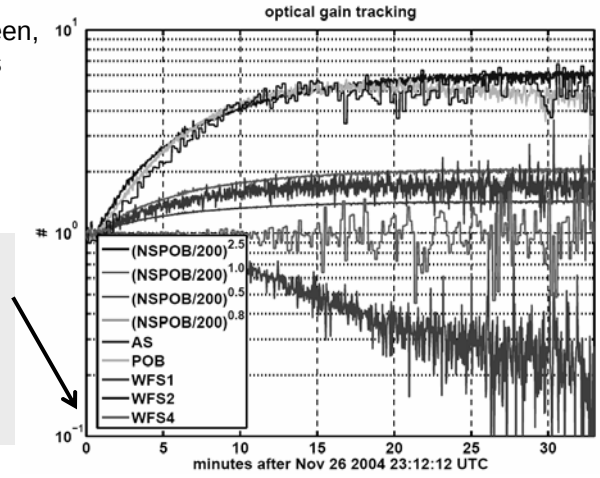
TCS on H1

- At 4 W into the mode cleaner, H1 requires annulus mask ('external cooling') to maintain optimal lensing
  - Evidence that ITMX (X-arm of Michelson) is over-absorbing
- Common control of TCS (both ITMs)
  - Set to point of maximum sideband buildup (maximum optical gain)
  - 'Bull's-eye' wavefront sensor being investigated to give a zero-crossing error signal
- Differential control of TCS (diff. between ITMs)
  - Reduces the coupling of RF phase noise, by equalizing the amplitudes of the RF sidebands
  - Error signal: I-phase signal at AS port (GW signal is in the Q-phase)

TCS on L1

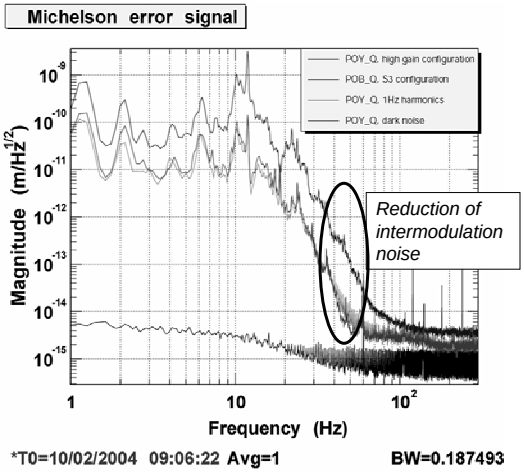
- No significant lensing seen, even up to several watts into mode cleaner ⇨ external central heating req'd

At T = 0, TCS was turned ON, with ~30 mW of CO2 power shining onto the center of each ITM ⇨ After 20 min, RF sideband power has increased by a factor of 2



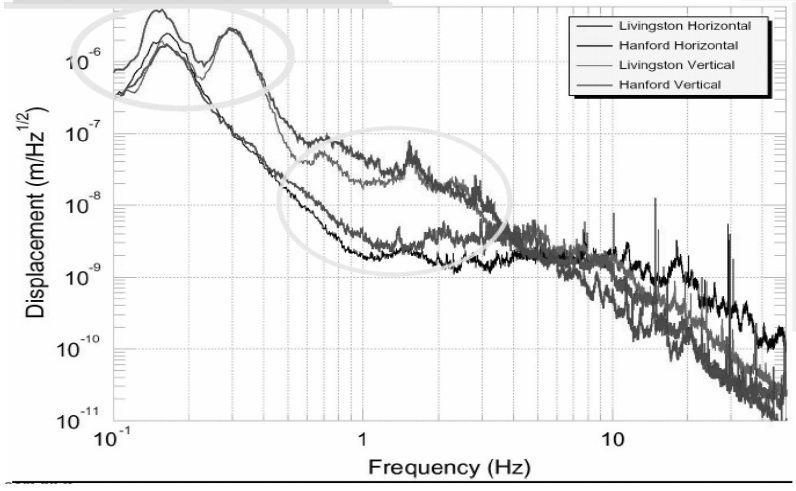
Auxiliary degrees-of-freedom: small coupling to GW channel, but very noisy

- Recycling cavity DOF (common & diff.): change of control strategy
  - S3: low bandwidth servos, plus low-pass filtering in the GW band; DOF too loosely held, suffered from intermodulation noise production
  - Now: higher-bandwidth servos, plus real-time subtraction of noise from GW channel
- Benefits
  - 10x or more reduction of PRC noise below ~100 Hz
  - Allows detection of higher power (10x) for these DOF, reducing shot noise region, above ~100 Hz



Seismic Noise: LLO vs LHO

Ocean activity, hurricanes

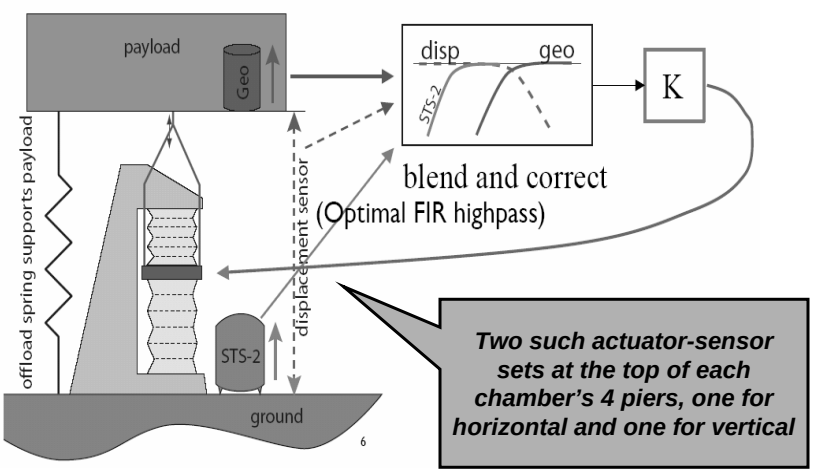


Human activity:

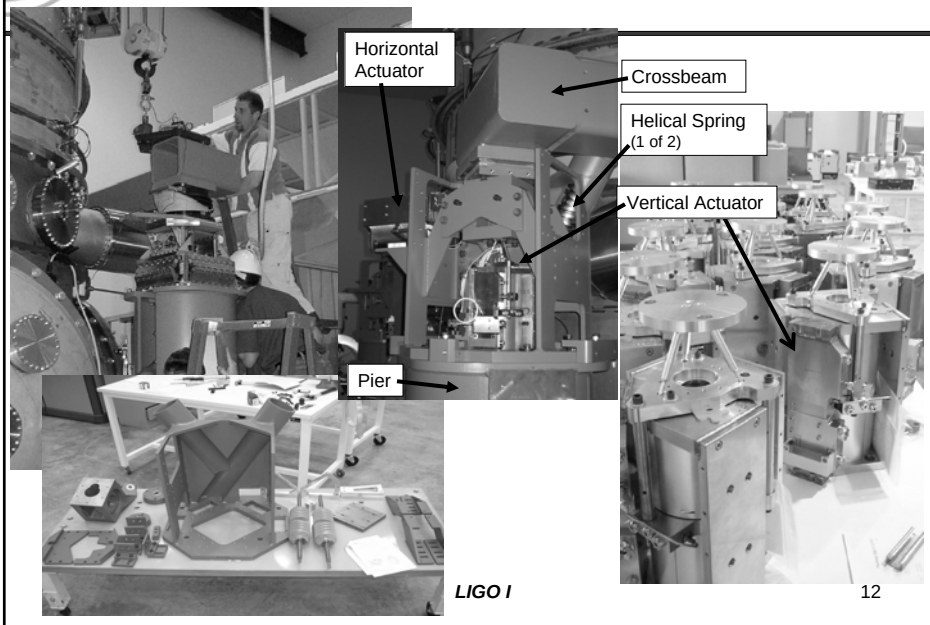
Cars
Trucks
Trains
Logging
Drilling

Amplified by stack resonances

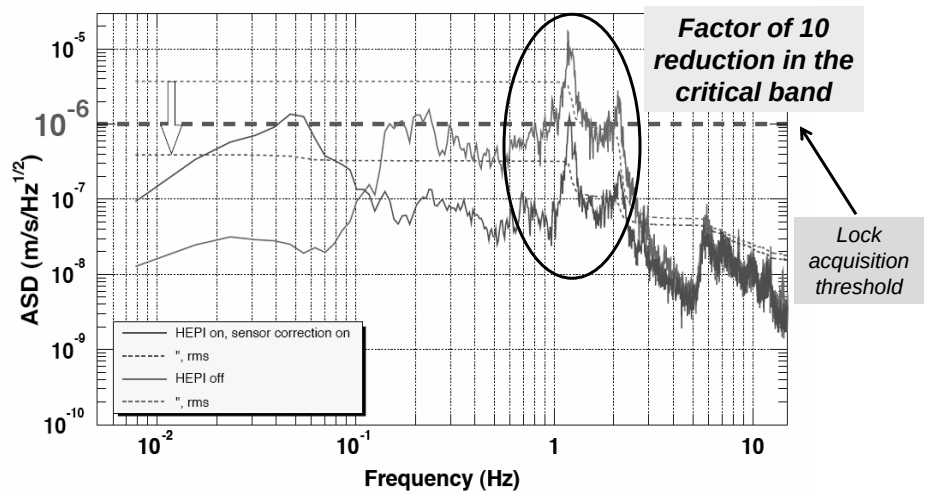
Hydraulic External Pre-Isolator (HEPI)



HEPI in pictures



HEPI performance on a noisy afternoon: *relative velocity between ITMX & ETMX*

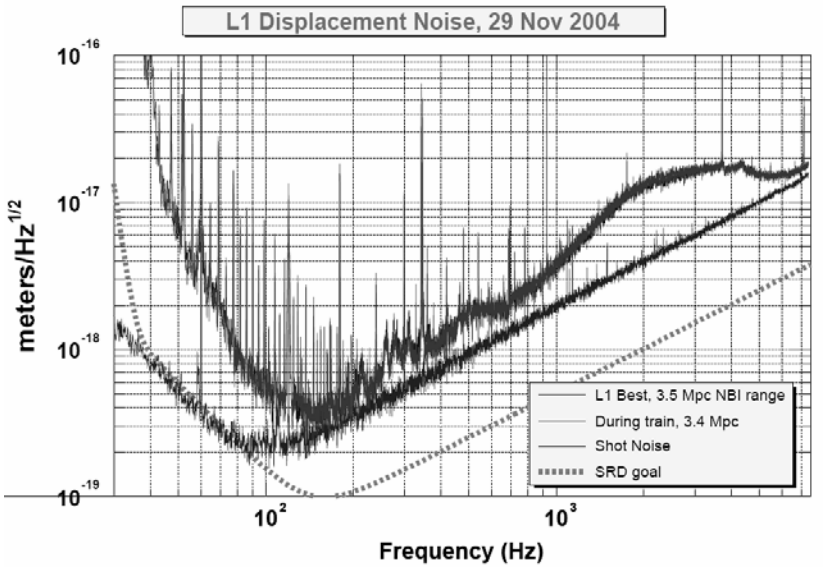


HEPI status

- **Installation complete, Mar-July 2004**
  - Keeping on eye on some hardware reliability issues
    - Had problems with actuator valve failure, sensor failure, corruption of sensor ADC data
  - Seems more reliable recently
- **Controls implementation**
  - All 5 BSC chambers (test masses & beamsplitter) have full isolation in all DOF (still room for tweaking the servo filters/gains)
  - Isolation control for HAM chambers being developed
- **Impact**
  - *For the first time at LLO, allows locking and commissioning of the full interferometer during the day!*

Latest L1 performance

3x improvement over S3, even during local train passage!

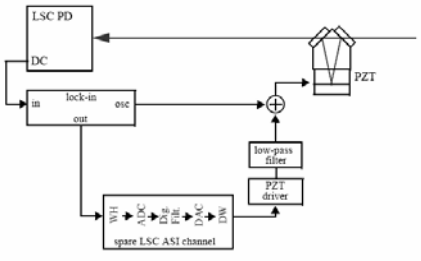


15

Output mode cleaner: tests of the GEO OMC on H1

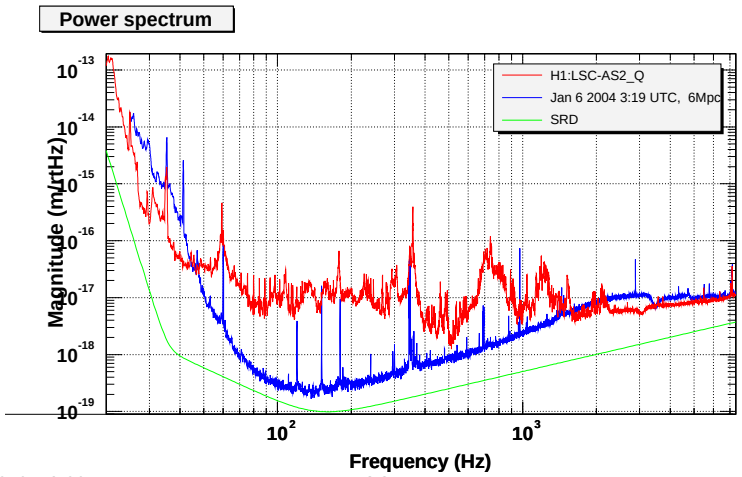
The Good

- Carrier contrast defect improves by a factor of 20
  - With OMC: carrier 2% of total power
  - Makes it possible to reduce modulation depth
- Removes offset corresponding to 10^{-12} m
  - Reduced AM noise coupling: factor of 60 at 3 kHz
  - Reduced oscillator phase noise coupling: factor of 2 at 3 kHz
- ASI signal decreases by a factor of 7
  - "ASI locking" symmetrizes RF sidebands

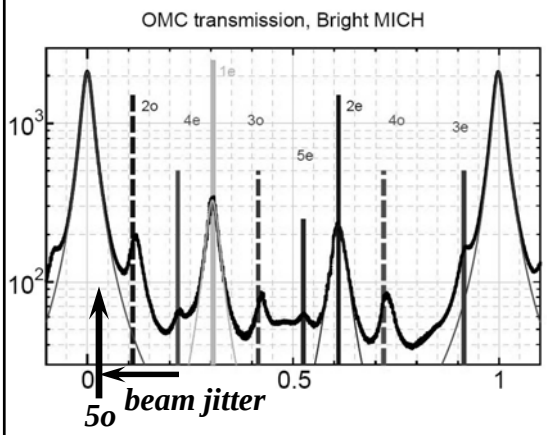


Would be able to operate with a single PD at AS port!

Output Mode Cleaner
The Bad



Output Mode Cleaner
The Ugly

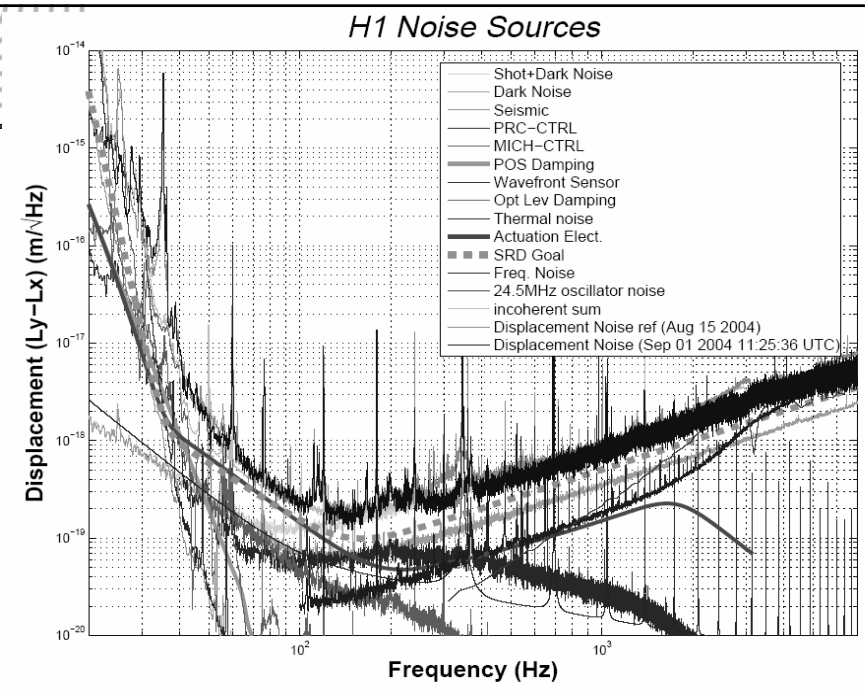


- Higher order modes & beam jitter generate a PDH-like signal
- Elliptical beam is a problem
- Triangular cavity geometry is a problem
- Operation in air is a problem

• A new 4-mirror OMC has been designed, built and is being tested
• Designs for an in-vacuum implementation are being considered

Miscellaneous improvements

- New low-noise D-A converters from Freq. Devices Inc.
  - 30-40 dB lower noise
- New Faraday isolator for H2
  - Larger aperture to reduce clipping
  - Lower absorption for higher power operation
- Photon calibrators
  - In place on H1
- Reduce glitches due to dust falling through AS beam
  - better layout with bigger beams + dust covers for beam path
- New laser power stabilization servo
  - Lower intensity noise above 1 kHz
- Upgraded DAQ reflective memory network
  - higher capacity & CRC checksums
- Micro-seismic feedback system to fine actuators at LHO
- 100 kHz DAQ channels, w/ heterodyning
  - new GW channel at the arm cavity first free-spectral-range (37kHz)



Commissioning/Run plan

- E11 just completed at LHO, 17-23 Nov
  - Inspiral range: 6.5-7 Mpc; Duty cycle: 65% overall, 75% over last 4 days
  - Time for commissioning efforts to respond to problems found in the data (glitchiness, e.g.)
- E12 for LLO scheduled to start 1 Feb 2005 (1 wk)
- S4 to start on or around 23 Feb 05, if all goes well
- Performance goals for S4: 4 week run
  - Inspiral range:
    - H1: 7.5 Mpc
    - L1: 4 Mpc
    - H2: 2 Mpc
  - Duty cycle: 70% individual, 40% triple coincidence
- S5: one year of coincident data at the science goal sensitivity
  - Run should start early 2006