Status of the LIGO Detectors

6th EDOARDO AMALDI CONFERENCE,
Okinawa, June 21, 2005

Daniel Sigg, LIGO Hanford Observatory

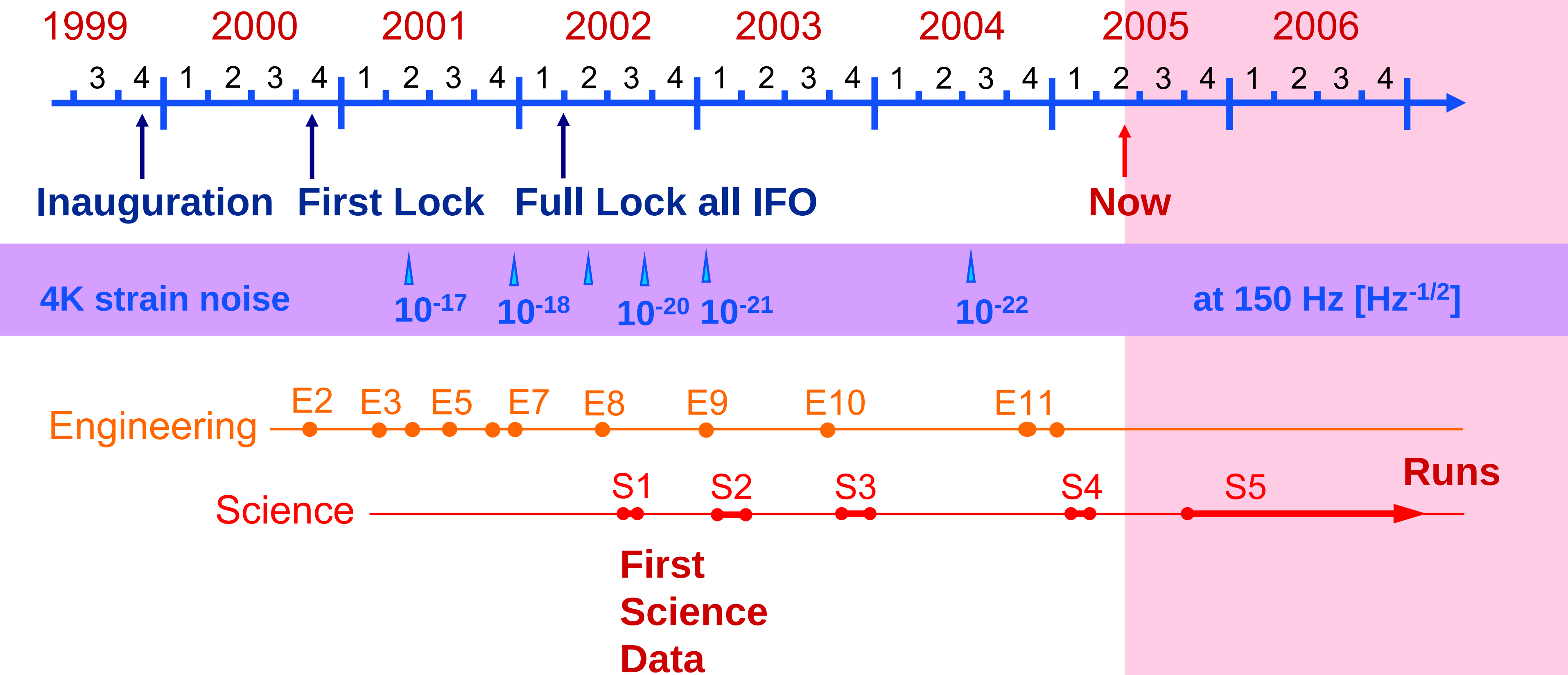
G050300-00-D

Arial View of the LIGO Sites

LIGO Hanford Observatory

LIGO Livingston Observatory

Time Line

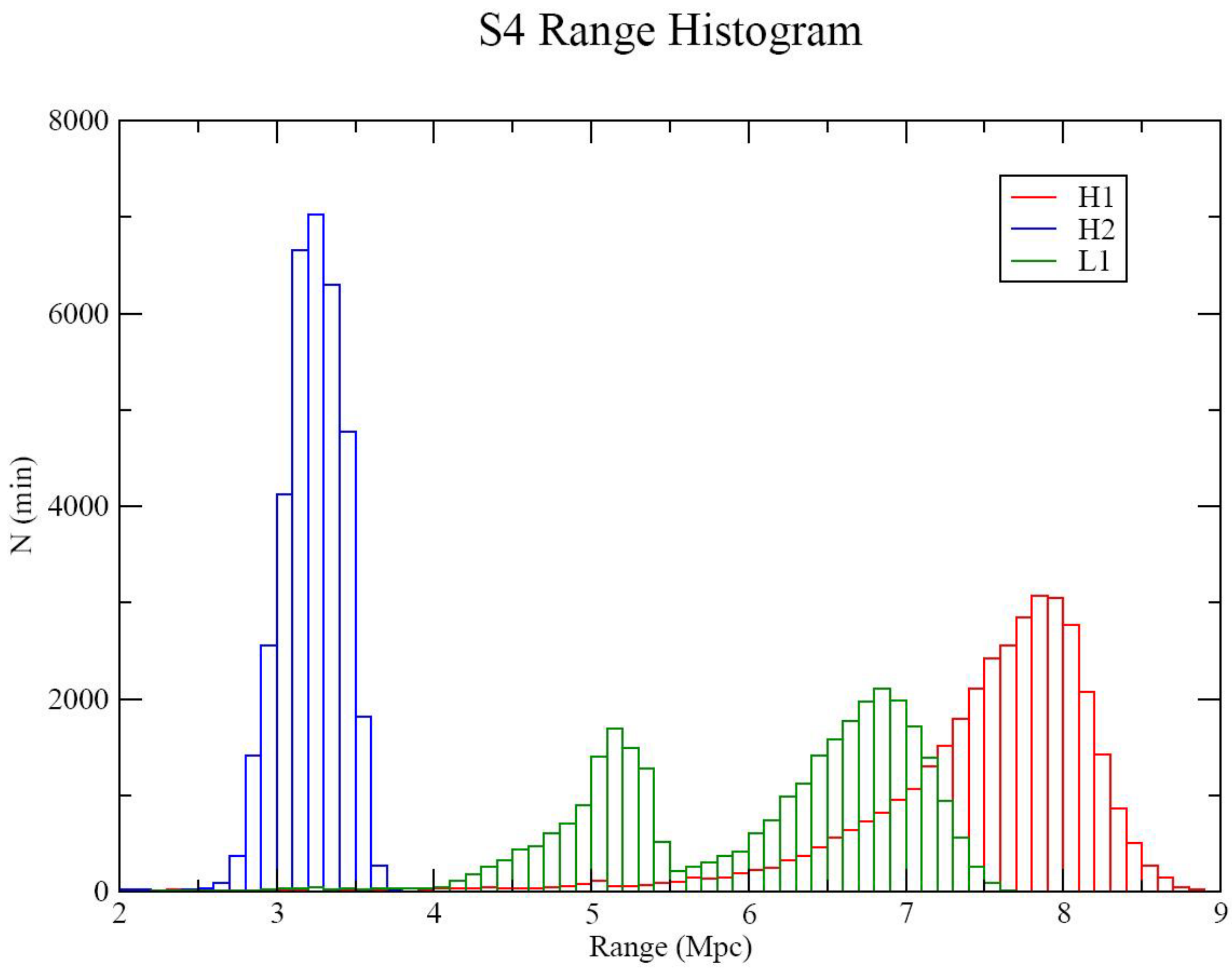

1999
2000
2001
2002
2003
2004
2005
2006
3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Inauguration
First Lock
Full Lock all IFO
Now
4K strain noise
10-17
10-18
10-20
10-21
10-22
at 150 Hz [Hz-1/2]
Engineering
E2
E3
E5
E7
E8
E9
E10
E11
Science
S1
S2
S3
S4
S5
Runs
First Science Data

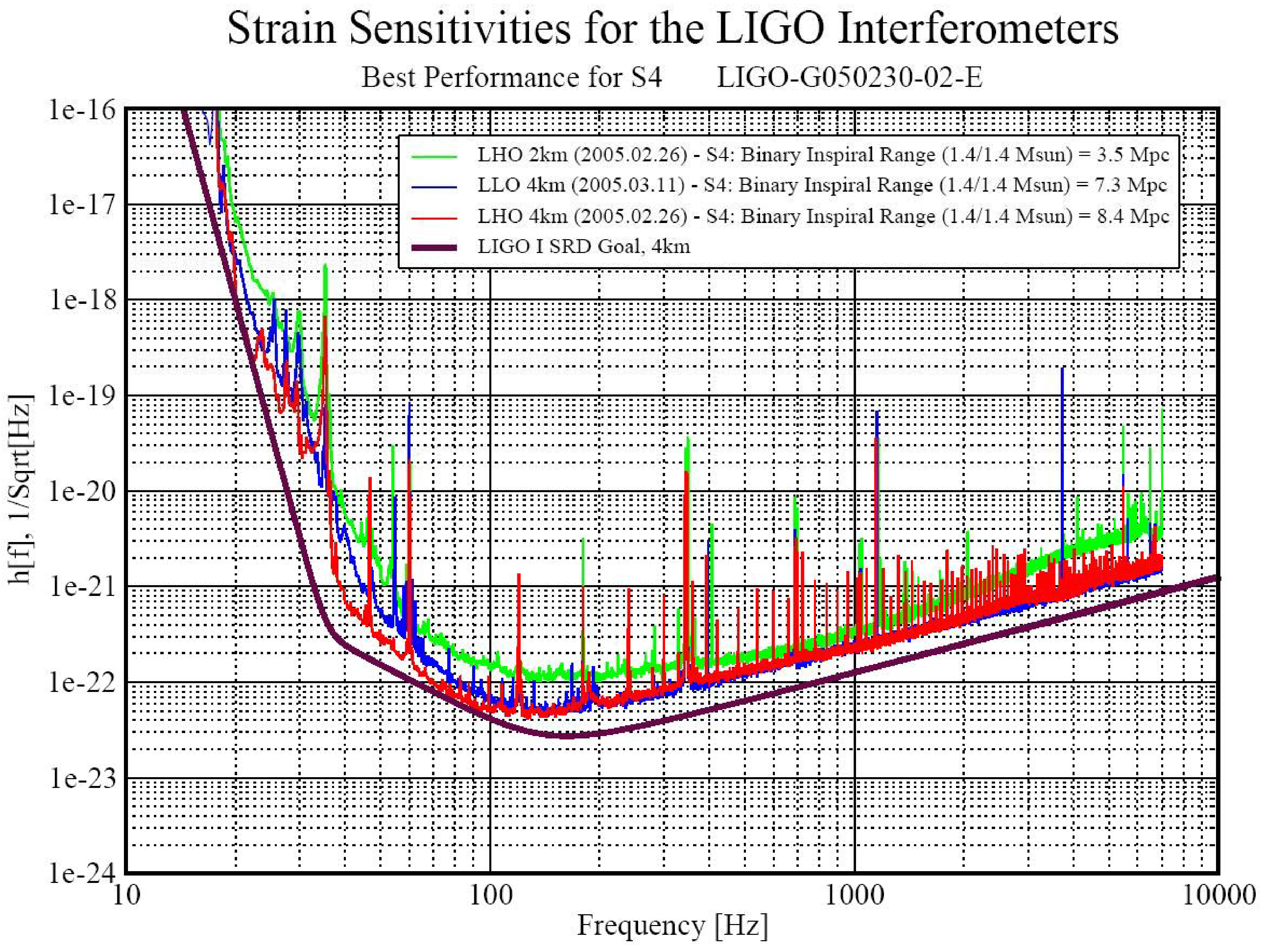
Major Achievements Since Last Amaldi

- An order of magnitude improvement in sensitivity (at 150Hz)
- All 3 interferometers within a factor of 2 of design
- Hydraulic external pre-isolator at Livingston
  - Success! Allows 24 hour operation
- Thermal compensation system
- Output Mode Cleaner Test
  - Some good features but “large” acoustic sensitivity
- S1/S2 analysis published, S3 analysis in progress, S4 run completed

The 4th Science Run

- Dates (2005):
  - Start: 22 Feb
  - Stop: 23 Mar
- Duty cycle:
  - H1: 80%
  - L1: 74%
  - H2: 81%
  - Triple coincidence: 57%

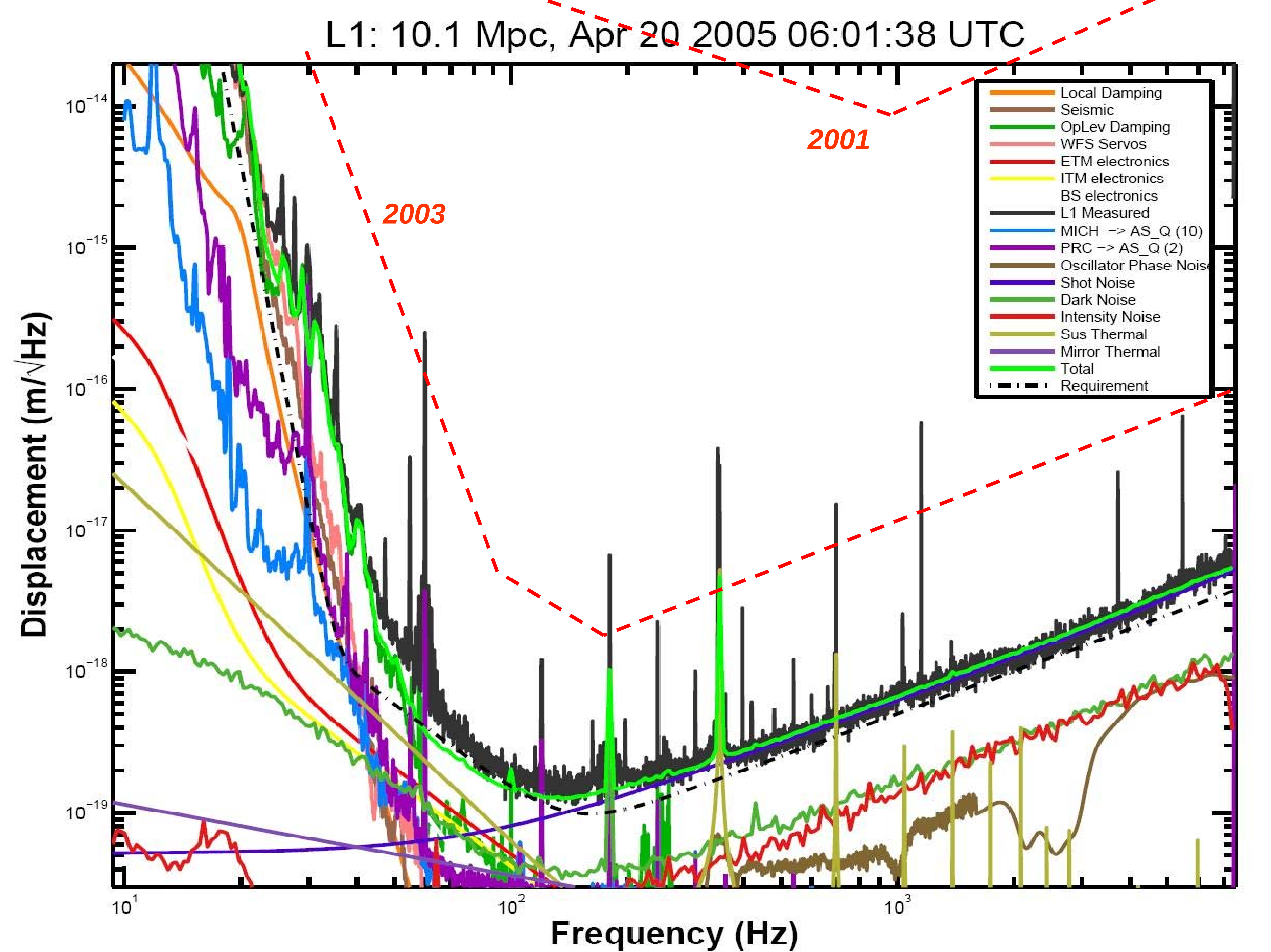




Strain Sensitivities for the LIGO Interferometers
Best Performance for S4 LIGO-G050230-02-E
LHO 2km (2005.02.26) - S4: Binary Inspiral Range (1.4/1.4 Msun) = 3.5 Mpc
LLO 4km (2005.03.11) - S4: Binary Inspiral Range (1.4/1.4 Msun) = 7.3 Mpc
LHO 4km (2005.02.26) - S4: Binary Inspiral Range (1.4/1.4 Msun) = 8.4 Mpc
LIGO I SRD Goal, 4km
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]

Results from the 1st/2nd Science Run

- **Binary inspirals (S2):**
  - Neutron star binary coalescence: range up to 1.5 Mpc, rate ≤ 47/y/MW (90% CL)
  - Black hole coalescence (0.2-1$M_\odot$) in Galactic halo: rate ≤ 63/y/MW (90% CL)
- **Pulsars (S2):**
  - Limits on 28 pulsars
  - Upper limits on h as low as 2×10^{-24} (95% CL) and as low as 5×10^{-6} on the eccentricity
- **Stochastic background (S1):**
  - Energy limit as fraction of closure density: $h^2_{100}\Omega_0 \leq 23 \pm 4.6$ (90% CL)
  - **PRELIMINARY** S2: $h^2_{100}\Omega_0 \leq 0.018 +0.007 -0.003$ (90% CL)
- **Burst (S2):**
  - Sensitivity: $h_{rss} \sim 10^{-20} - 10^{-19}$ /√Hz, rate ≤ 0.26/day (90% CL)
  - GRB030329: $h_{rss} \leq 6\times10^{-21}$ /√Hz



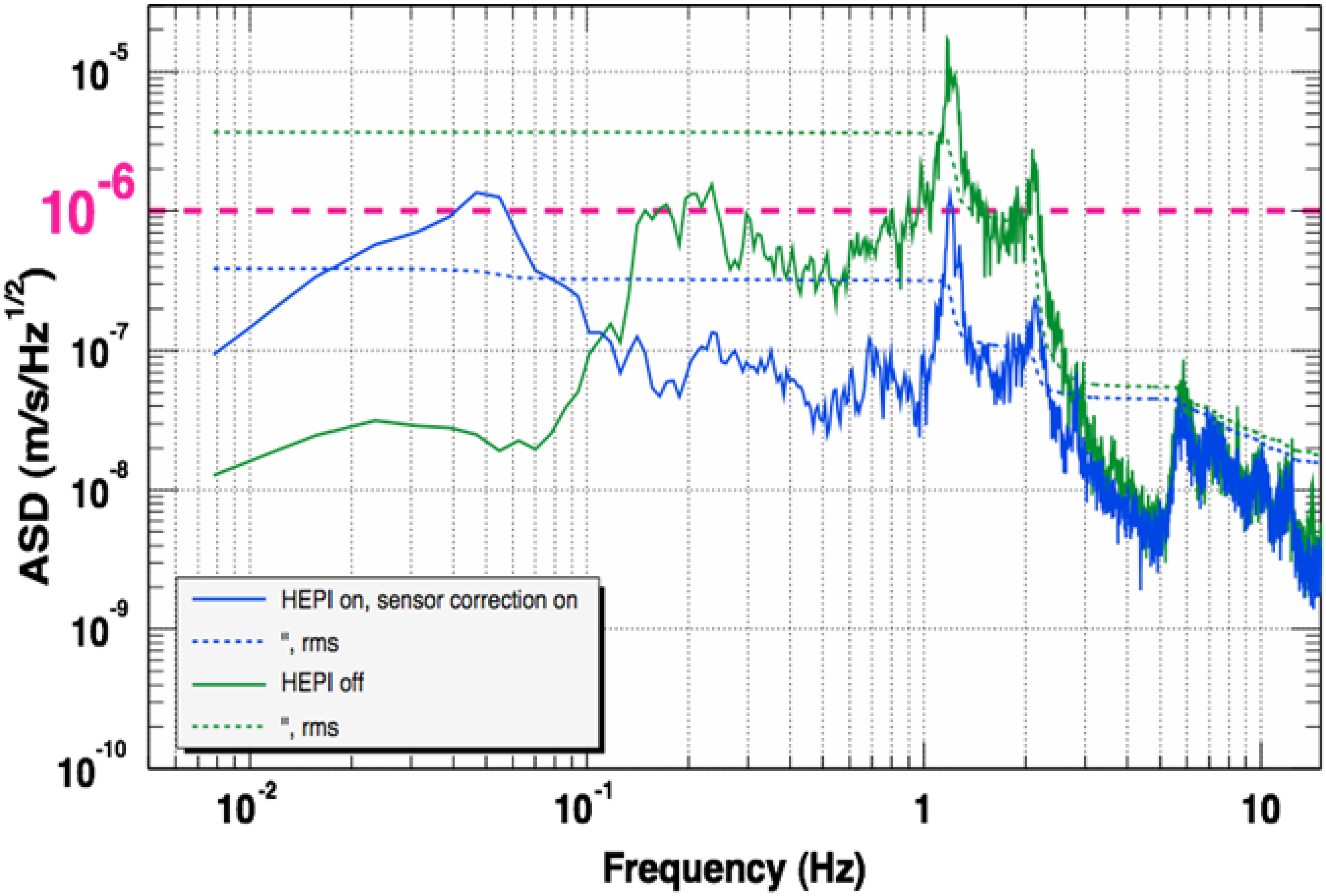
L1: 10.1 Mpc, Apr 20 2005 06:01:38 UTC
Local Damping
Seismic
OpLev Damping
WFS Servos
ETM electronics
ITM electronics
BS electronics
L1 Measured
MICH -> AS_Q (10)
PRC -> AS_Q (2)
Oscillator Phase Noise
Shot Noise
Dark Noise
Intensity Noise
Sus Thermal
Mirror Thermal
Total
Requirement
2001
2003
Displacement (m/√Hz)
Frequency (Hz)

Hydraulic External Pre-Isolator

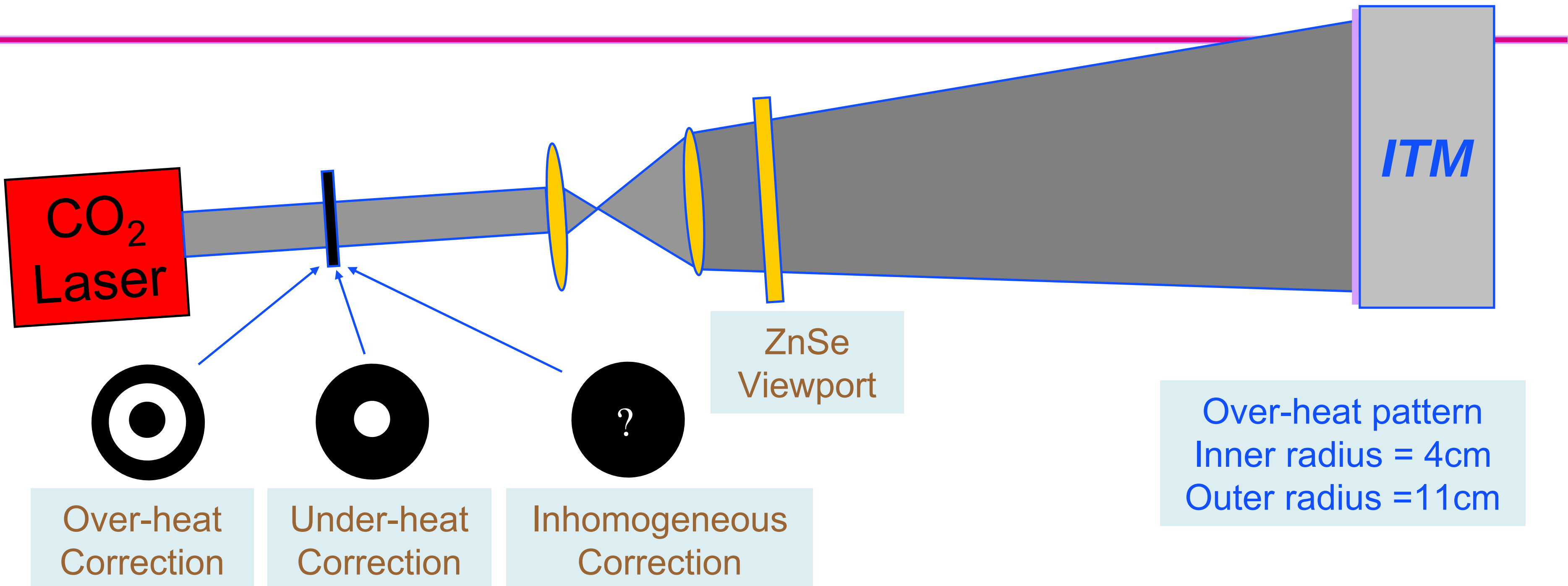
- The payload is supported by large coil springs, and actuated by quiet, high force hydraulic bridges.
- Vibration reduction is obtained by actively following inertial sensor signals from payload-mounted seismometers and by canceling floor vibrations.

X-arm length disturbance, noisy afternoon

- With HEPI in use, we expect the LLO detector to work on a typical noisy day, with at least a factor of 2 headroom.

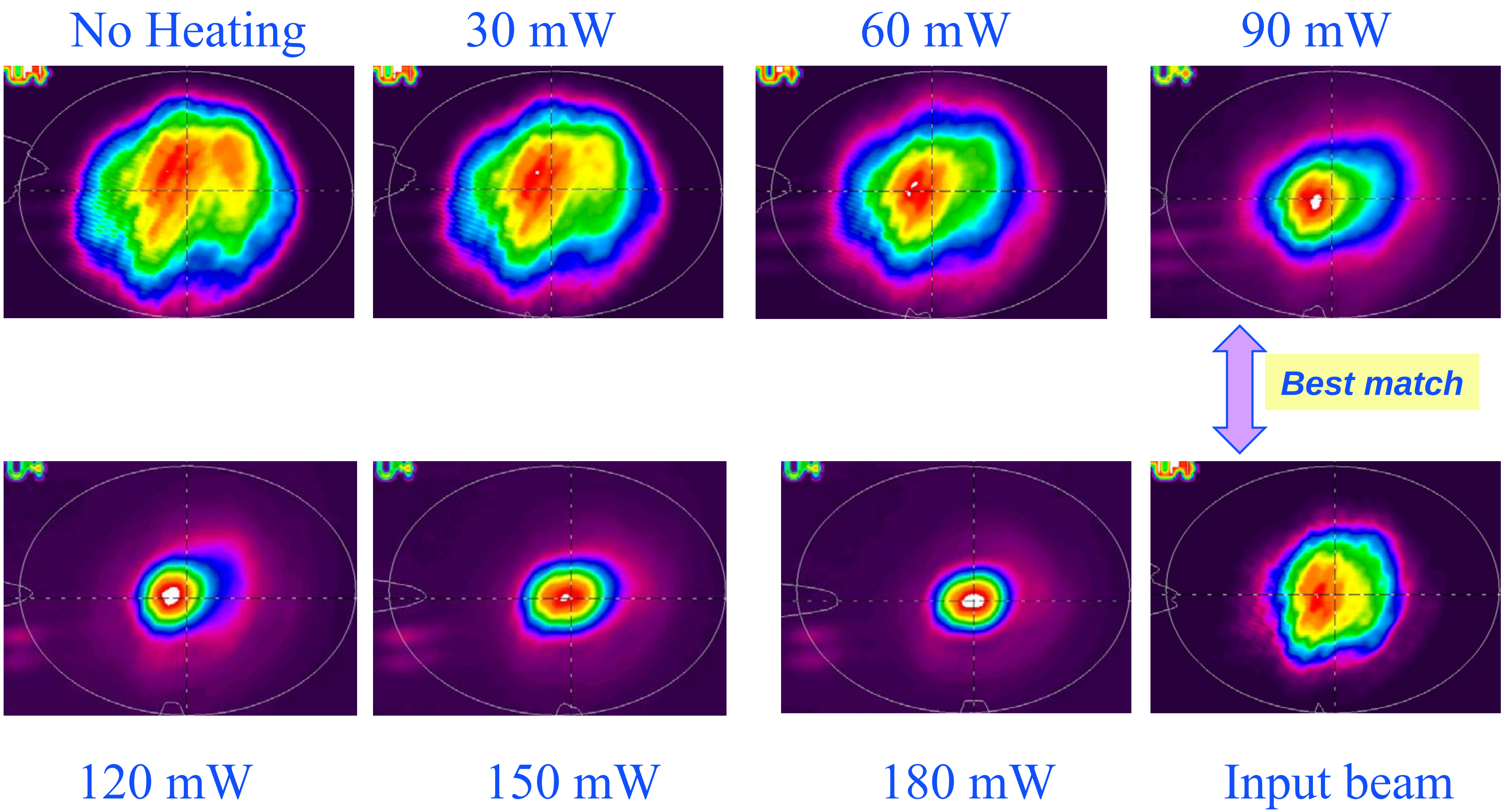


Thermal Compensation System



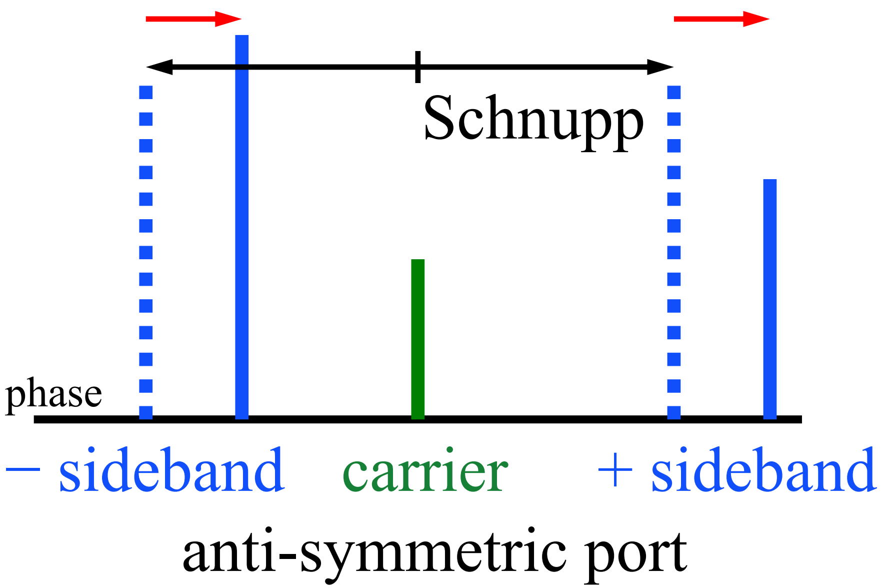
- Cold power recycling cavity is unstable: poor buildup and mode shape for the RF sidebands
- Require 10’s of mW absorbed by 1µm beam

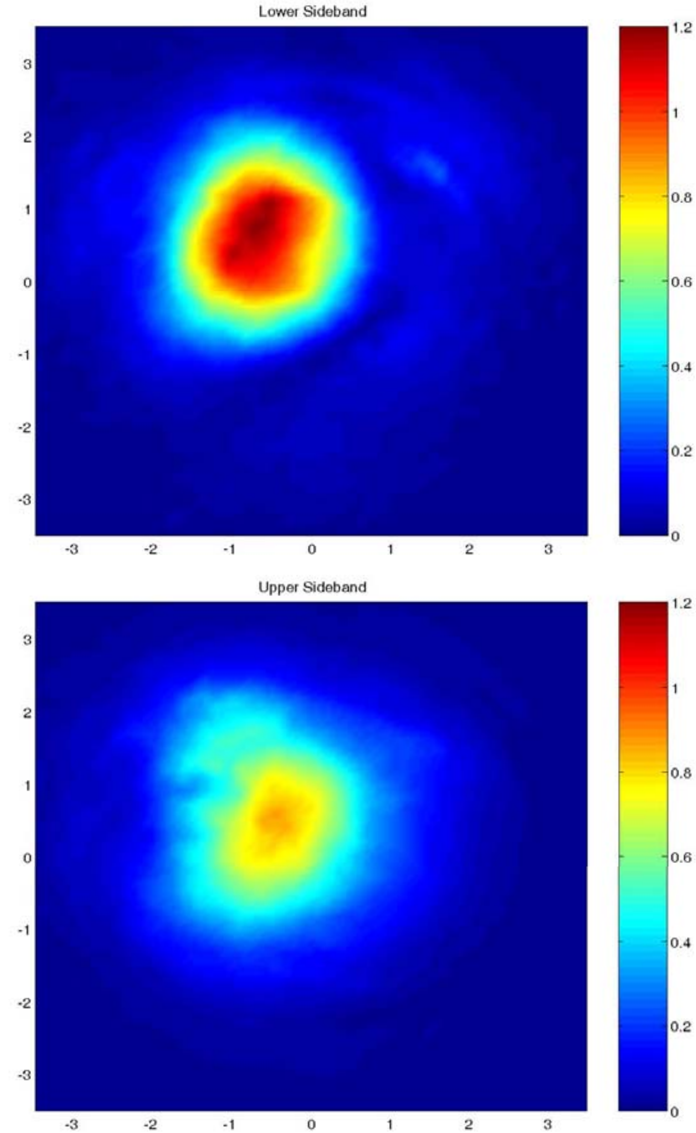
Sideband Images as Function of Thermal Heating



Sideband Imbalance

carrier/sideband mode mismatch





Other Commissioning Highlights

- Bull’s eye wave front sensor to servo the thermal compensation system
- Auto-alignment system at full bandwidth
- Low noise oscillator for main modulation
- Low noise digital-to-analog converters
- Acoustic mitigation and isolation improved
- Reworked common mode feedback path
- Better control on auxiliary degrees-of-freedom
- EMI improvements at LLO

Summary

- All LIGO interferometers are within a factor of 2 of design sensitivity over a broad range of frequencies
  - Thermal compensation essential to reach this sensitivity
  - Active pre-isolator essential at LLO to lock during work days
- For sources like binary neutron star coalescence we can see beyond our own galaxy!
- Join Einstein@home (einstein.phys.uwm.edu)