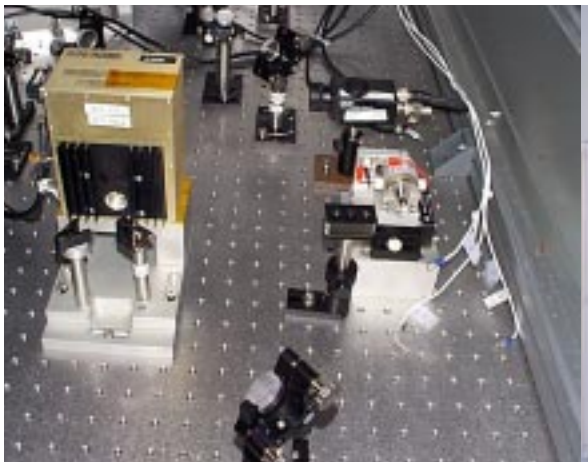
ACOUSTIC MITIGATION
PROGRESS



Robert Schofield, University of Oregon

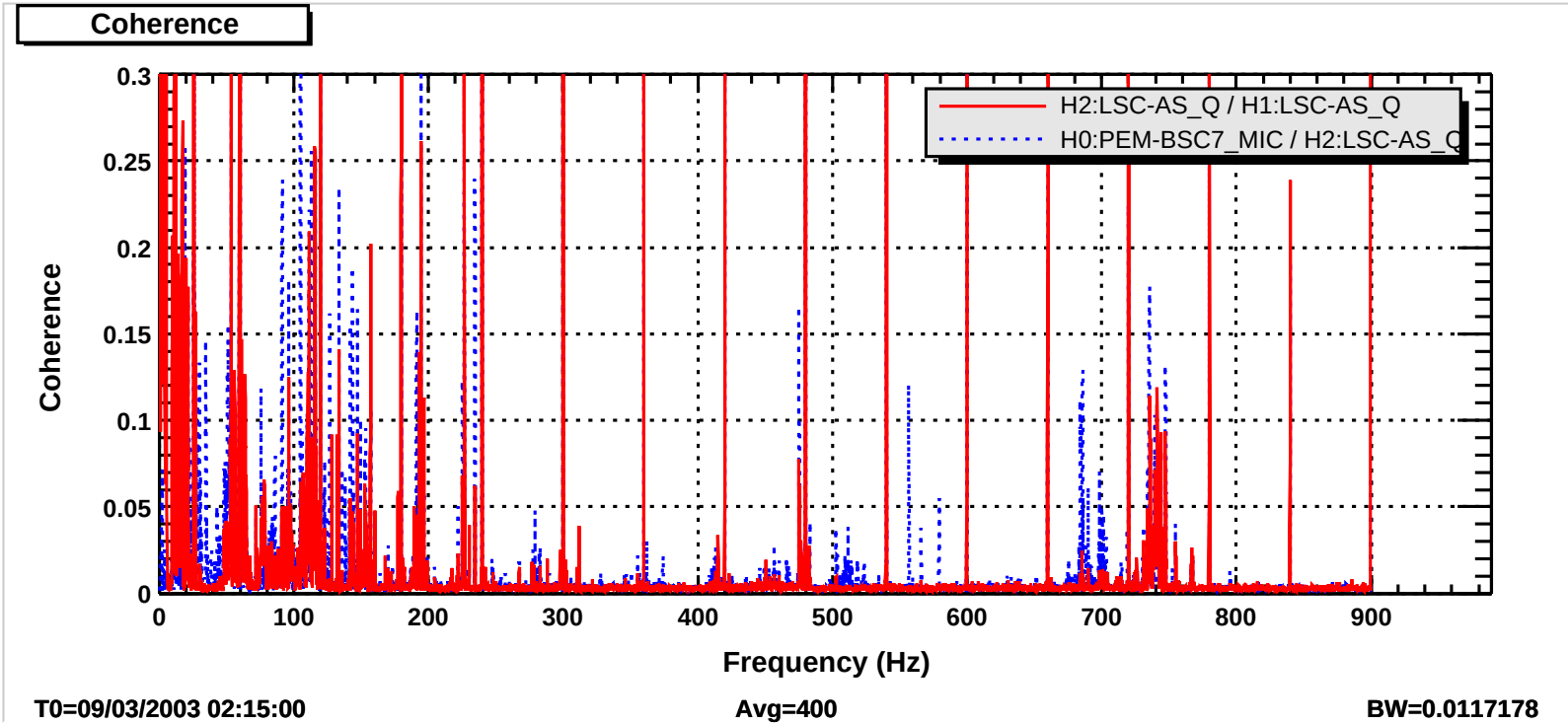
Doug Cook, Akiteru Takamori, LHO
Jonathan Kern, Joe Kovalik, LLO

AND MANY OTHERS

LIGO-G030496-00-Z

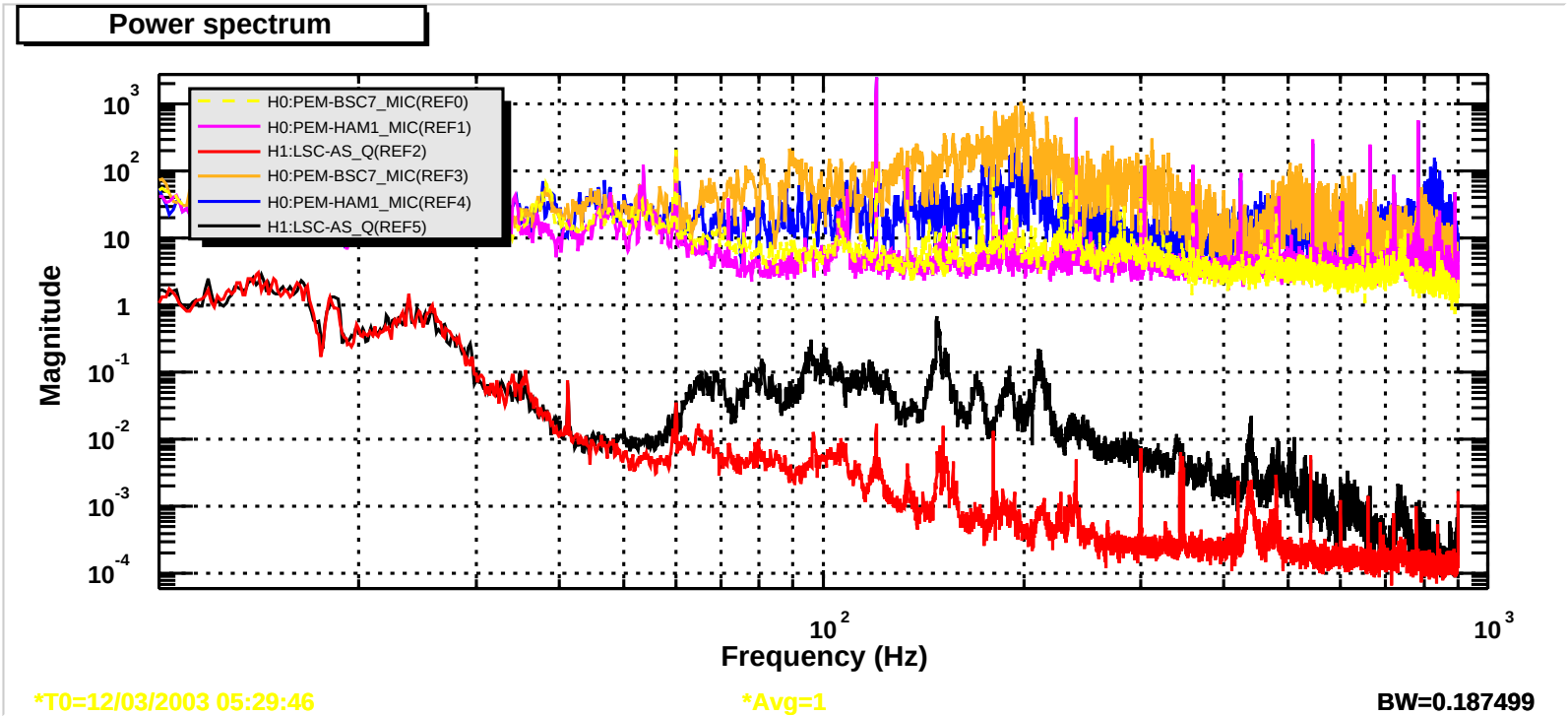
PROBLEM

Red shows coherence between H1 and H2 AS_Q over 12h during S2



Blue shows coherence between microphone near 4k dark port and 2k AS_Q

Noise played through speaker during S2 indicated that all three interferometers were close to being limited over a broad frequency range by acoustic coupling

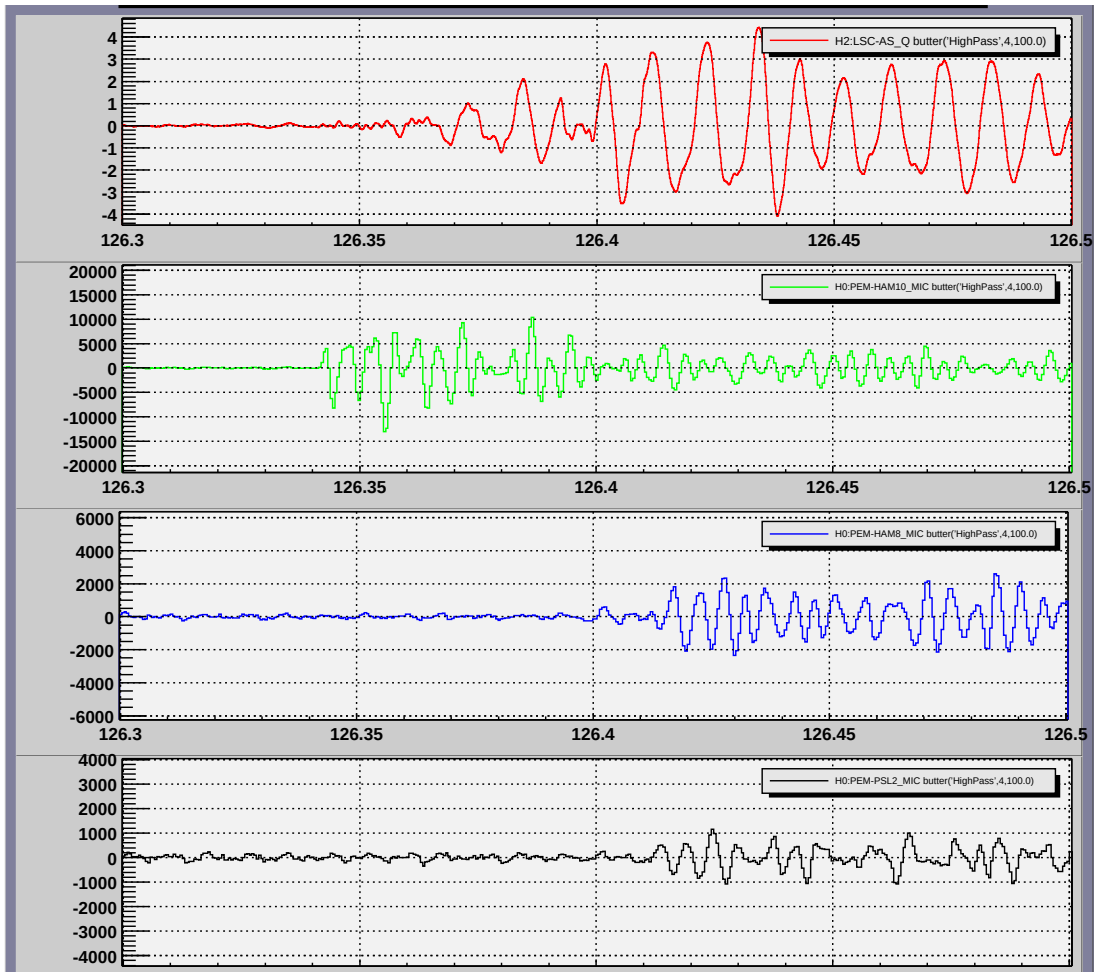


Black: AS_Q with noise; Red: normal; Orange: mic with noise; Yellow: normal

We would like to reduce acoustic-seismic contribution to noise by 100 to 1000

HOW COUPLING SITES WERE IDENTIFIED

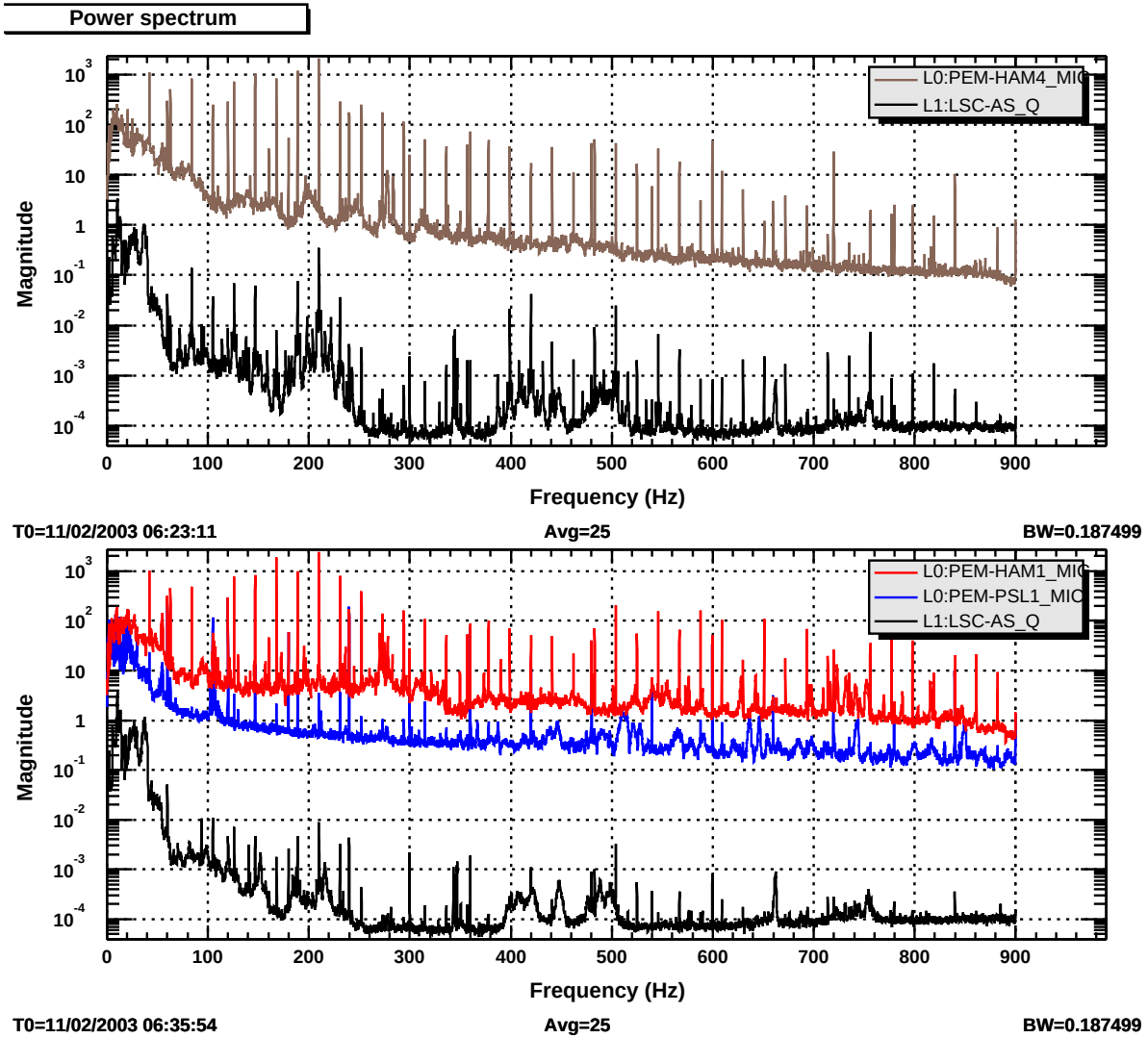
Burst propagation delays:



Predominant Coupling Sites : All 3 dark ports, LHO 4k PSL

HOW MUCH LOWER IS COUPLING AT OTHER TABLES?

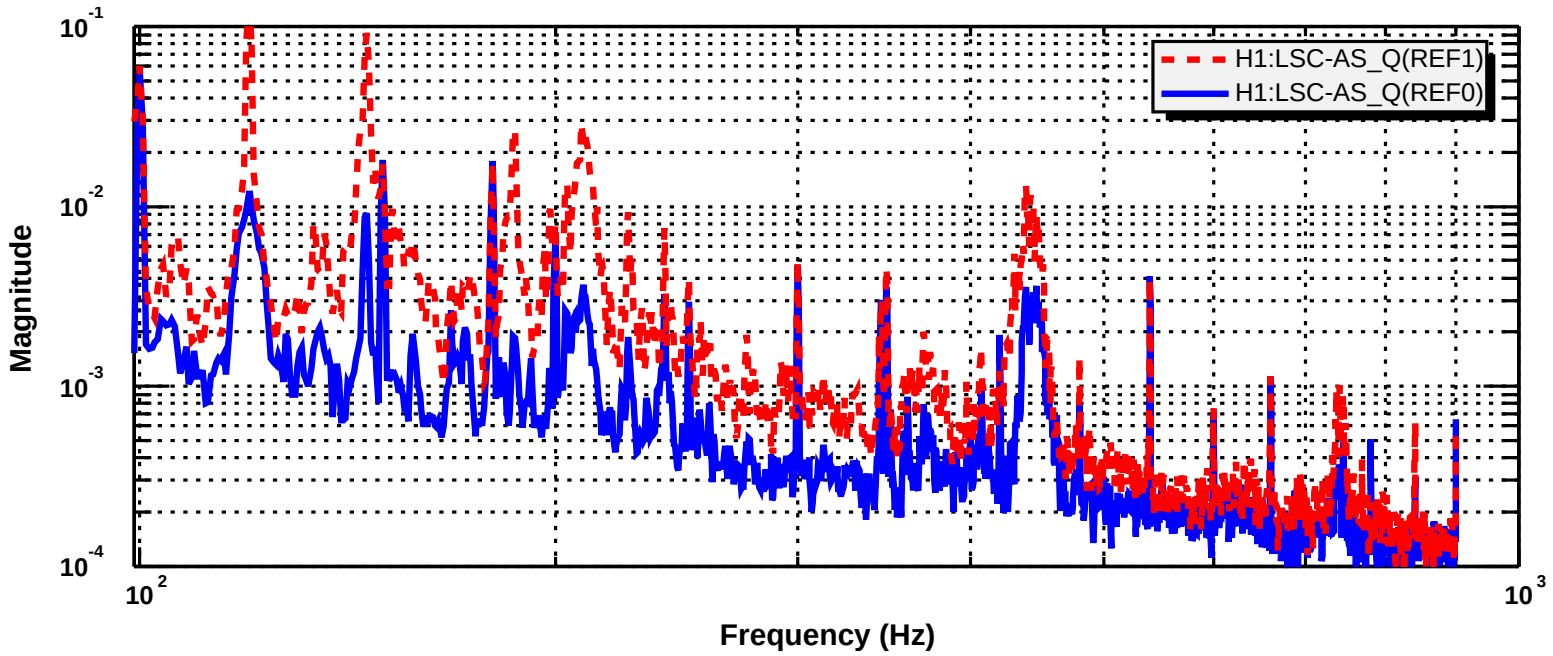
21 Hz sawtooth played near LLO ISCT4 (top), ISCT1 (bottom)



For S2 coupling at other tables is at least a factor of 10 lower than at dark ports.

MAIN COUPLING MECHANISM:
clipping modulated by acoustic excitation.

Evidence: acoustically excitable peaks in GW channel gradually increase as an iris on the dark port table is closed (see periscope peak just above 200 Hz). Calibration lines at harmonics of 50 Hz do not increase.

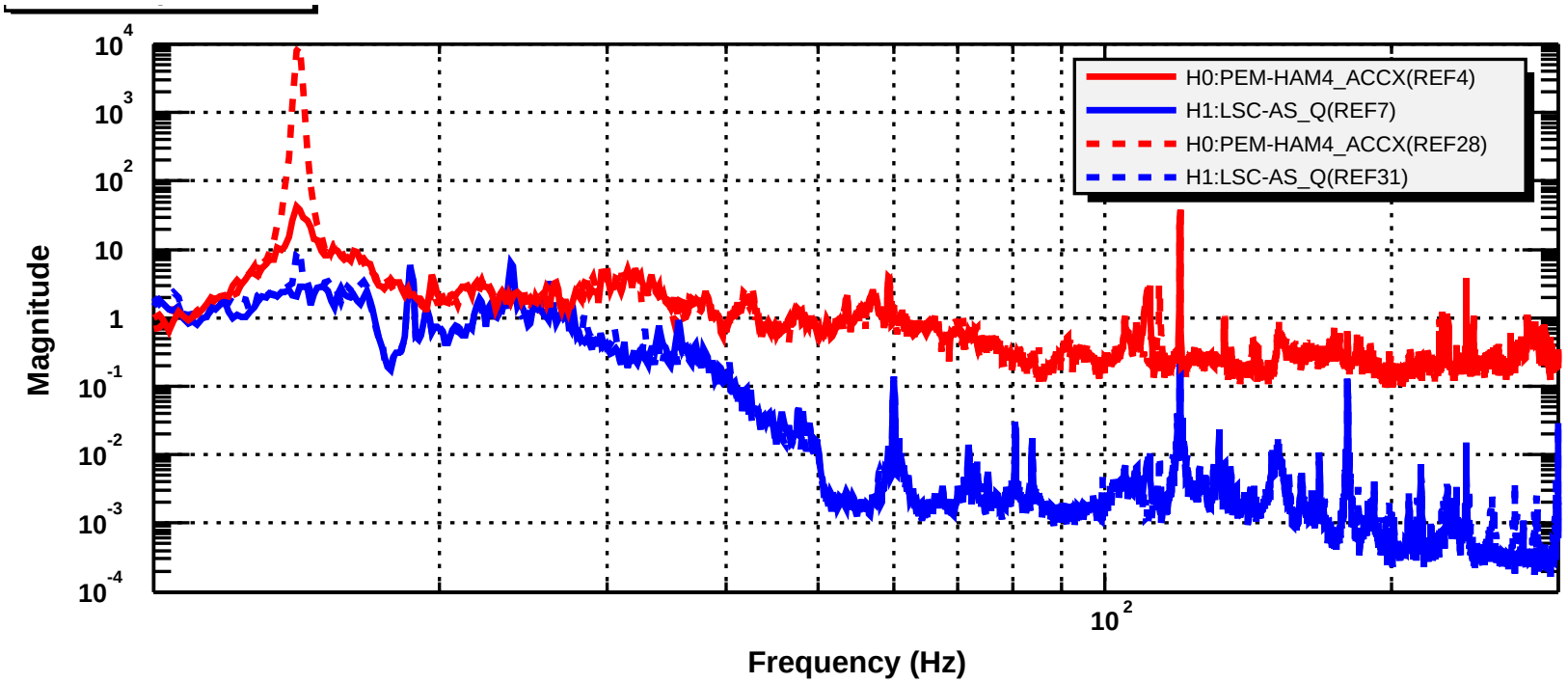


Blue: Normal; Red: Iris increased clipping

No evidence for parasitic interferometry noise from backscattering.

Red: Accelerometer on Dark Port Table; Blue: AS_Q

Solid: Normal; Dashed: Shaker shaking table at 14 Hz (sway resonance)



ACOUSTIC SOURCES

S2 LVEA sound levels are similar to those of an average residence

Location	dBC
near LHO 2k dark port, outside of ISCT10	50
near LHO 4k dark port, outside of ISCT4	53
near LHO 2k reflected port, outside of ISCT7	56
1m from ajar electronics rack	59
1m from closed electronics rack	57
1m from vacuum pipe feed-through into mechanical room	56
mechanical room	65-70
bay between mechanical room and LVEA	52

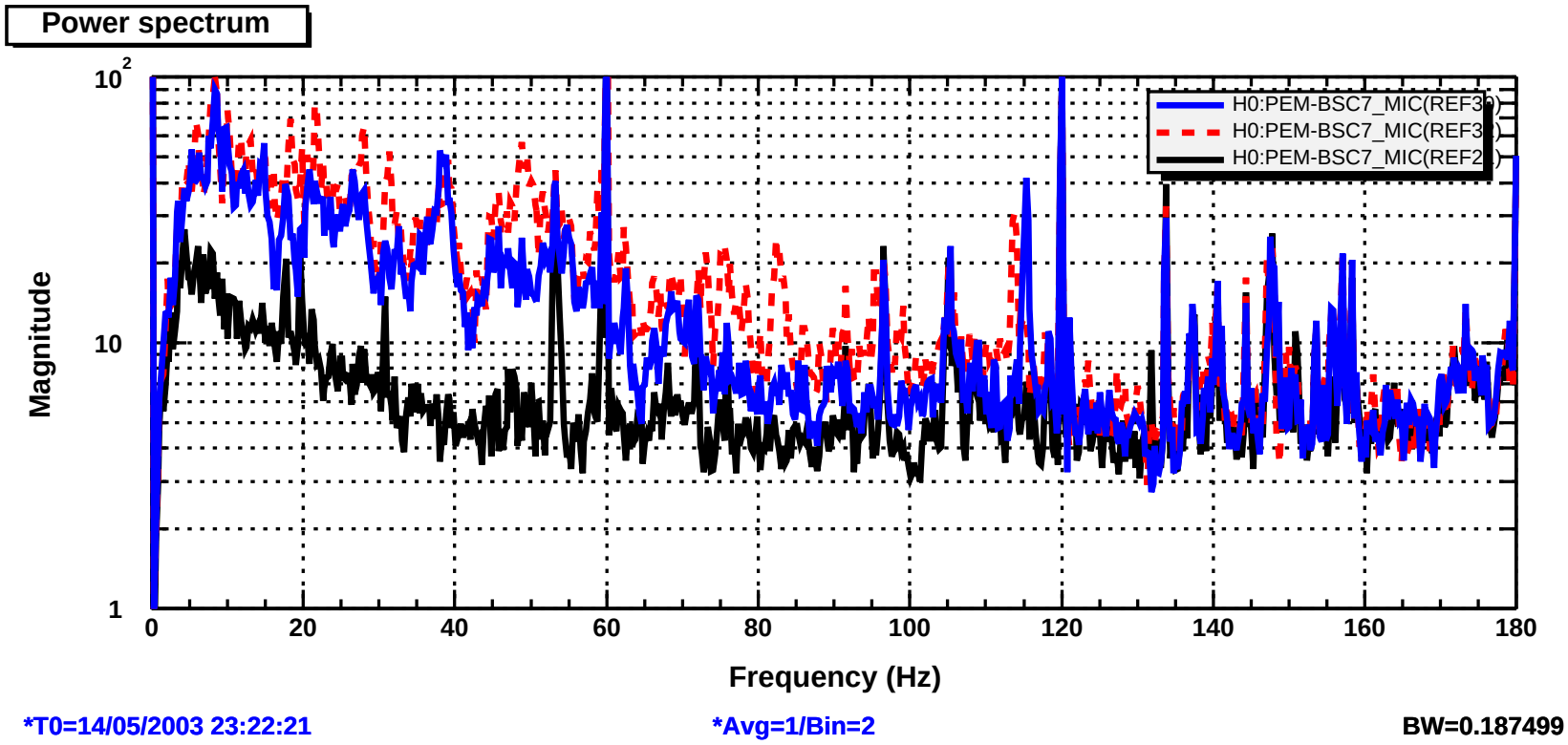
Continuous sources: mostly HVAC and electronics fans
Transients: building relaxation, airplanes etc.; these are hard to control and comparable in loudness to our fans etc.

For Burst Group analysis there isn't much to gain by reducing our lab sound level. However, continuous acoustic sources are important for the Stochastic Group.

LOUDEST CONTINUOUS SOURCES:
HVAC below 100 Hz, electronics cabinets above.

Rattling ducts may contribute to HVAC noise

Black: HVAC off, LVEA mic; Blue: HVAC on; Red: hand rattling of single walled duct.



PROPAGATION FROM SOURCE TO COUPLING SITE

Speaker on floor outside LLO triple PSL enclosure: comparison of inside to outside sensors

Frequency Hz	Microphone: Outside/ Inside	Accelerometer: Outside/ Inside
100	29	17
200	114	89
500	111	67
800	100	100

Enclosures appear to reduce table acceleration as well as sound pressure level.

Signal seems to travel predominantly through the air.

MITIGATION PLANS

I. REDUCE COUPLING (factor of 10 to 20)

A. Clipping

1) Eliminate some clipping sites (e.g. EO shutter)
2) Larger optics where needed; lighter mounts for higher resonant frequencies
3) Damp mounts and dumps etc.
4) New periscopes with higher frequency resonances and damping
5) Reduce table resonances around 100 Hz

B. Backscattering from table (out of prudence - we haven't seen coupling)

1)Rigid legs or float table

II. ACOUSTICALLY ISOLATE WORST COUPLING SITES (factor of 10 to 20)

A. Dark port enclosures with internal absorption kits

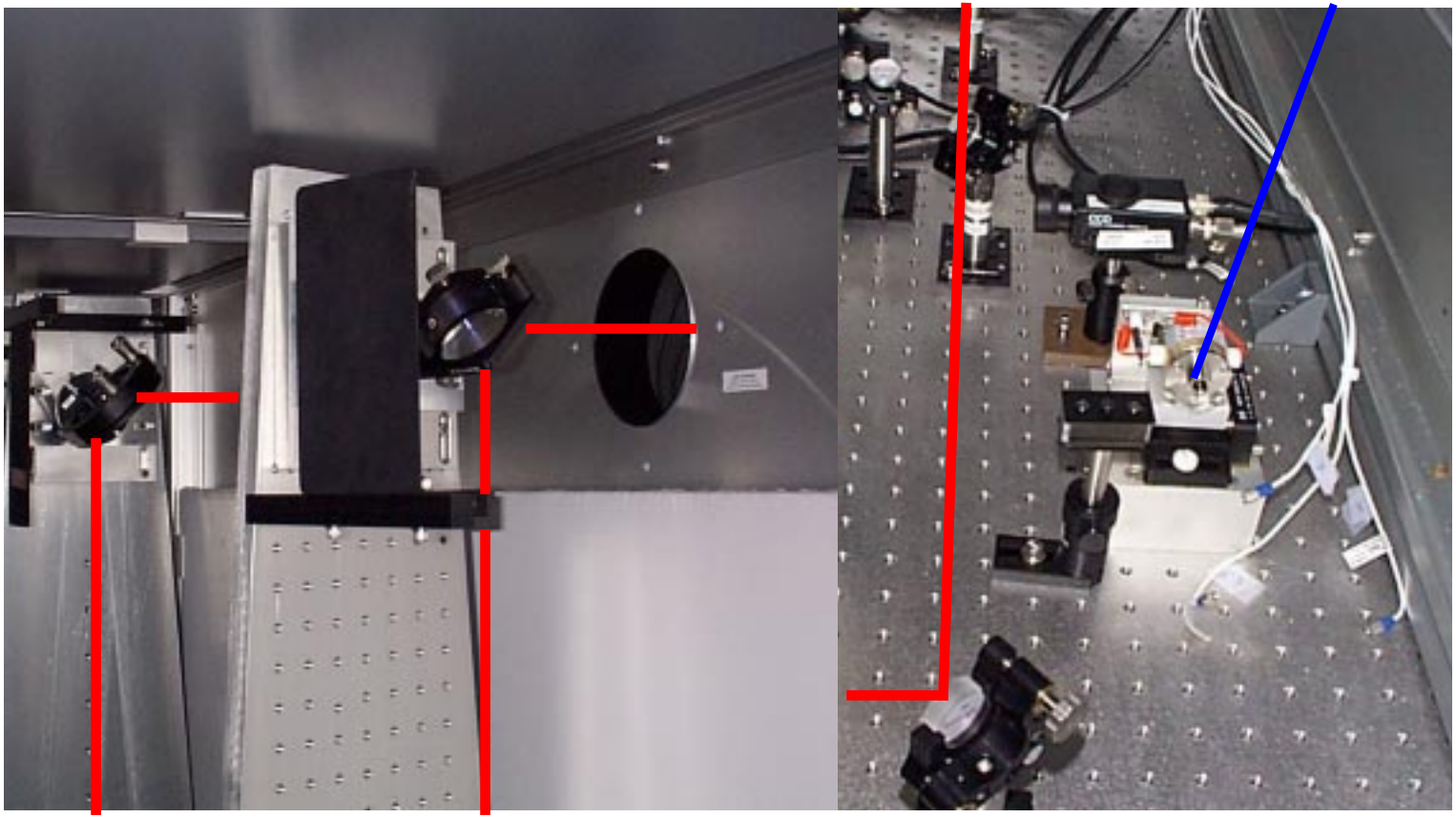
III. REDUCE CONTINUOUS SOURCES (factor of 3 to 5)

A. Remove most electronics cabinets from LVEA
B. Absorption and damping kits for vacuum electronics cabinets
C. Damp single walled sections of ducts
D. Insulate pipe feed through from mechanical room
E. Insulate PSL chillers

CLIPPING MITIGATION SINCE S2

1) Replaced the top optic mount on the dark port periscope with a lighter one
2) Eliminated some small apertures since S2: EO shutter and associated polarizers

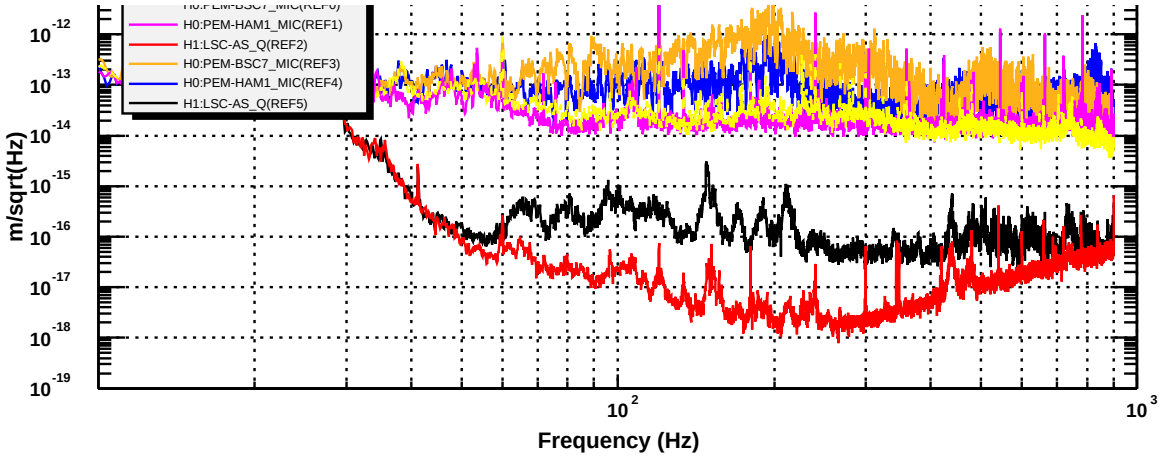
Old Mount New Mount New Path EO shutter sidelined



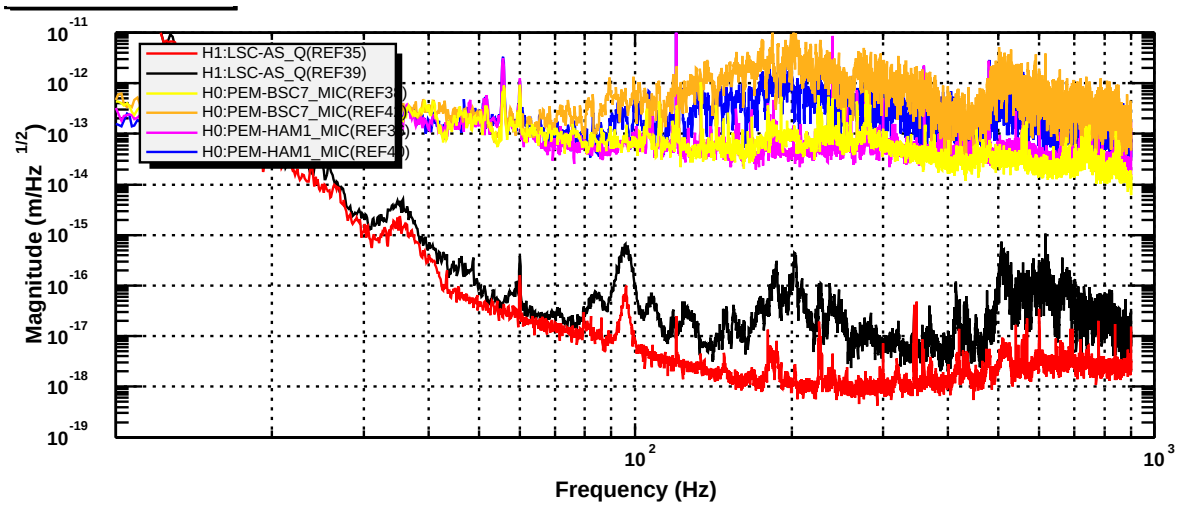
REDUCTION IN ACOUSTIC COUPLING SINCE S2

Red: AS_Q normal; Black: AS_Q with noise; Yellow & Orange: BSC7 mic

March 12

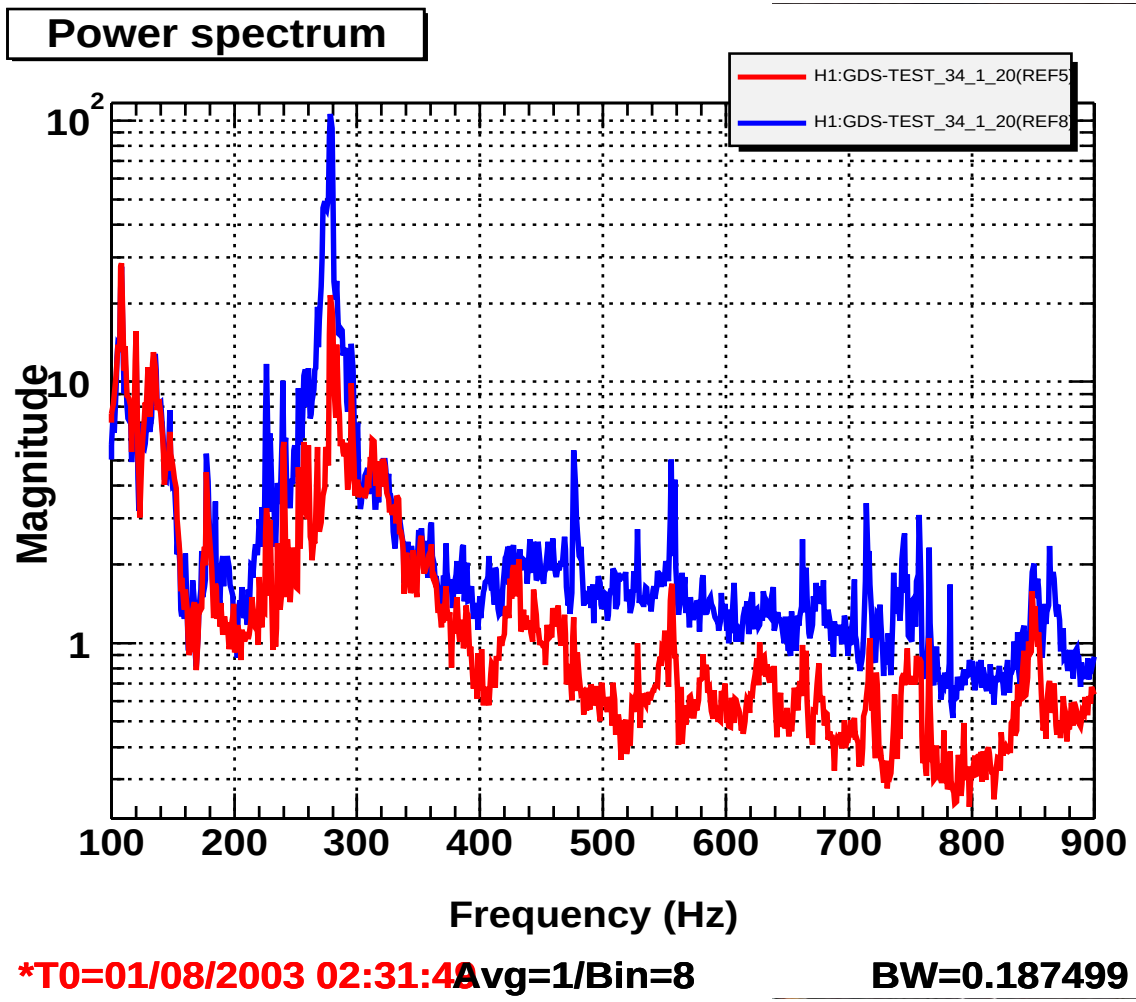


August 9



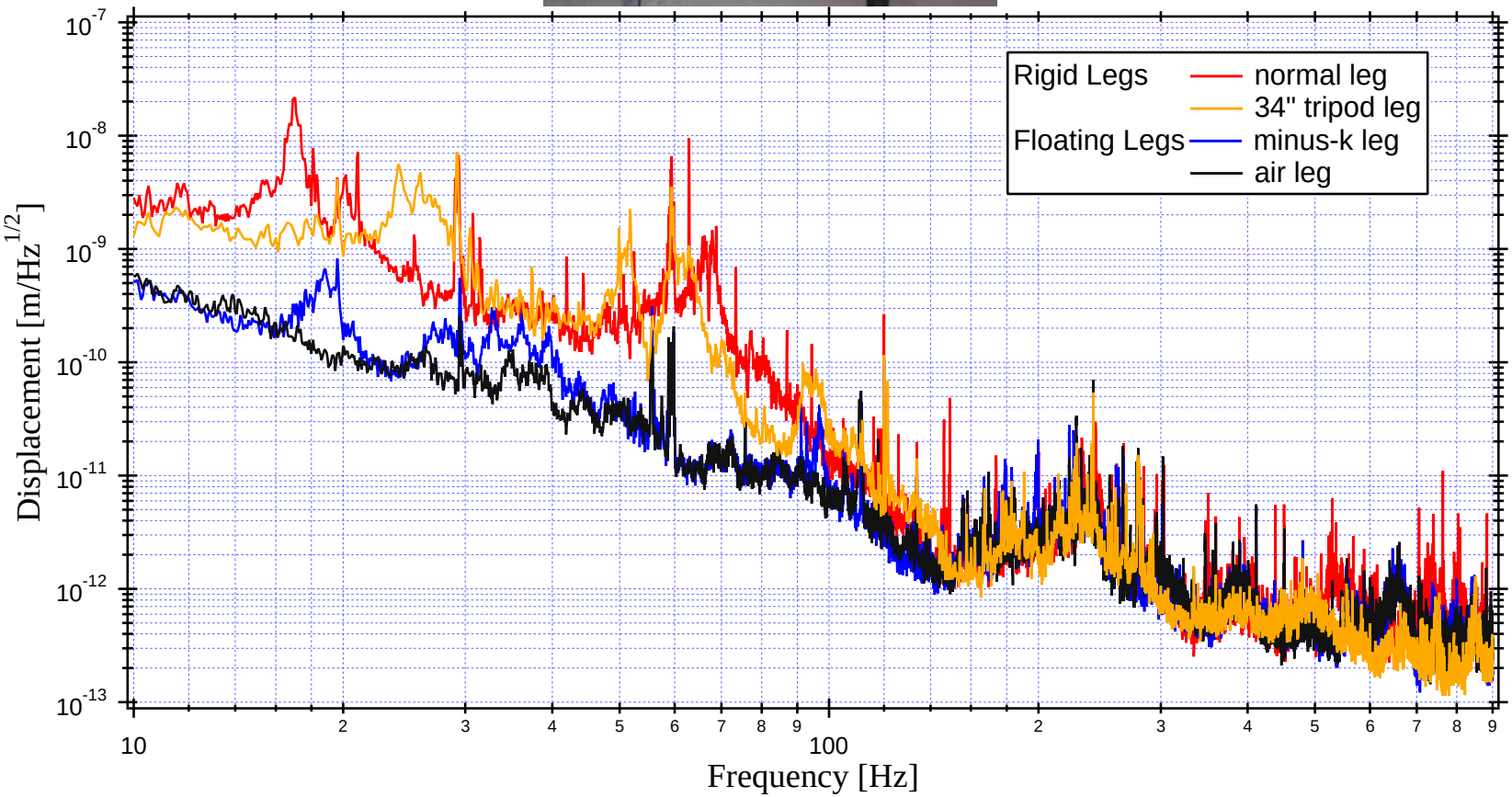
TESTING OF NEW PERISCOPE DESIGN WITH DAMPING

Accelerometer on periscope top; Blue: no damping Red: damping



Damping

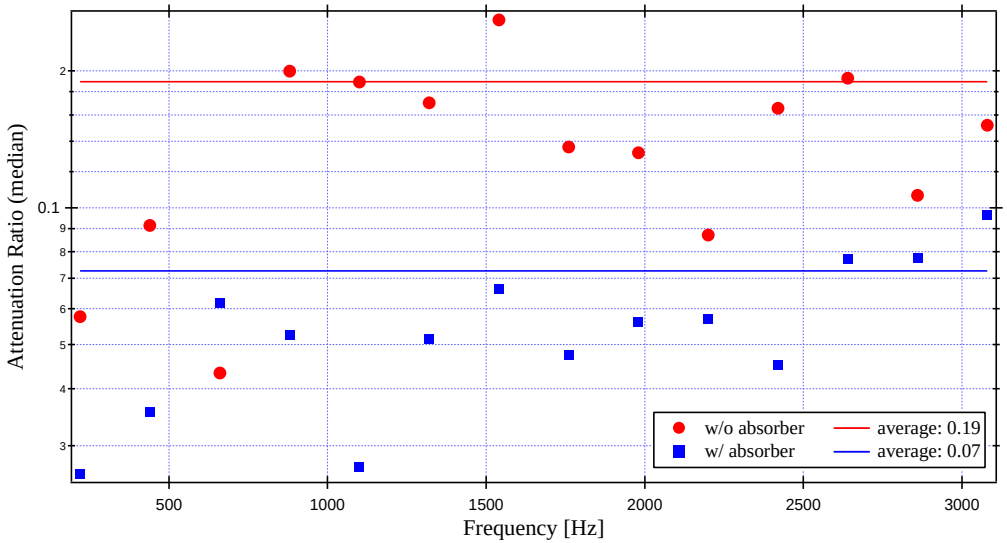
TESTS OF RIGID AND FLOATING TABLE LEGS



Sum in quadrature of 3 accelerometer axes

DARK PORT ENCLOSURES WITH ABSORPTION KITS

Enclosure: attenuation factor of about 10 at low f; with absorption kit, 20 to 30



MITIGATION OF CONTINUOUS SOURCES:

Remove 4k electronics cabinets from LVEA, place 2k cabinets in acoustic enclosures, internal absorption for vacuum cabinets and PSL chiller enclosures.

Damp sections of single walled ducts.