Results from test of new Earthquake Stops for LIGO Large Optics Suspension performed at LASTI

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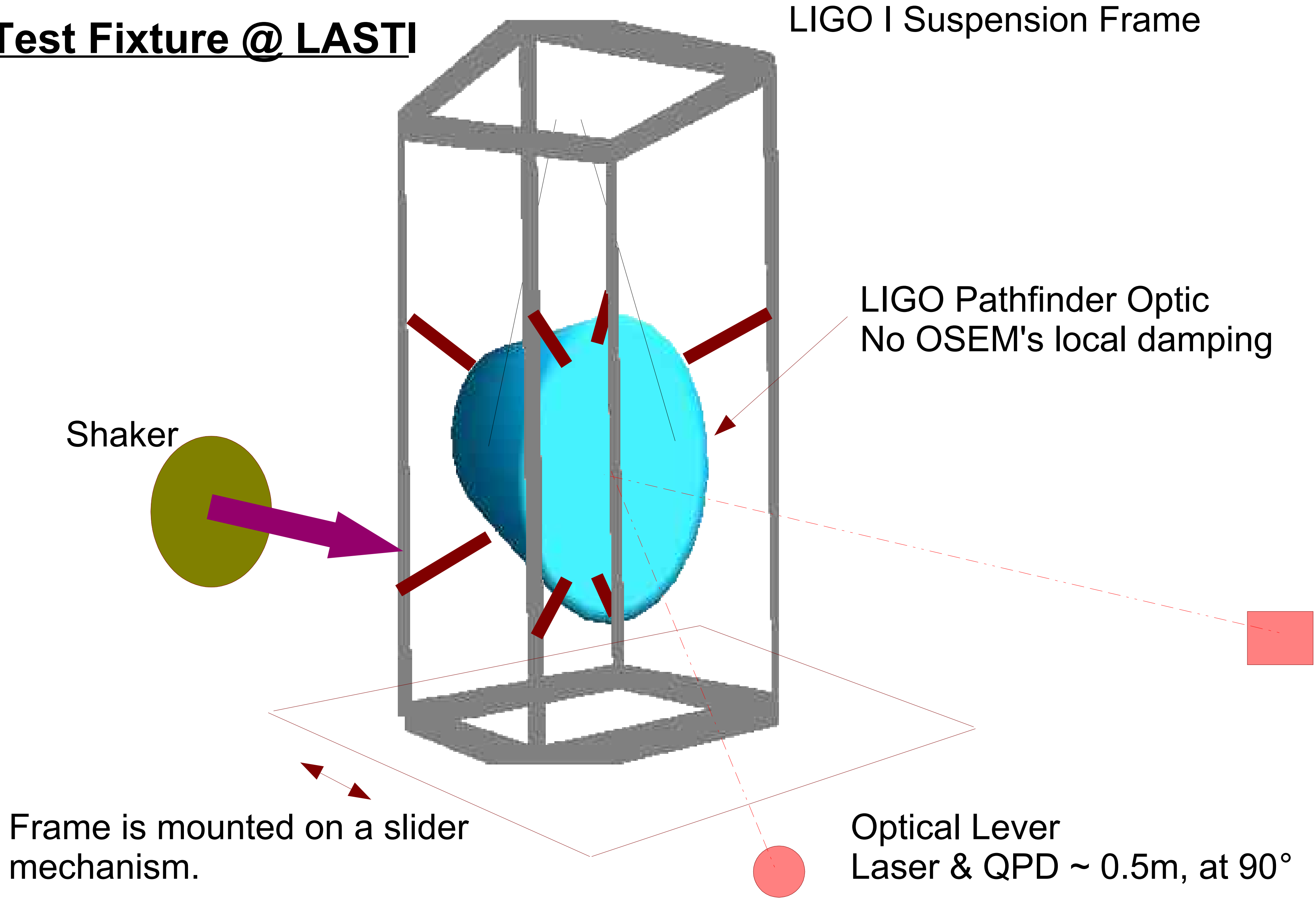
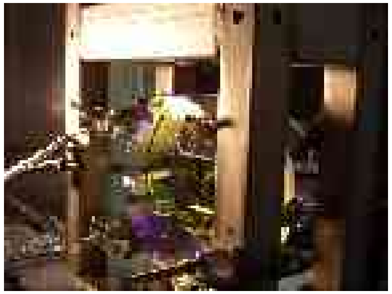
Test Fixture @ LASTI



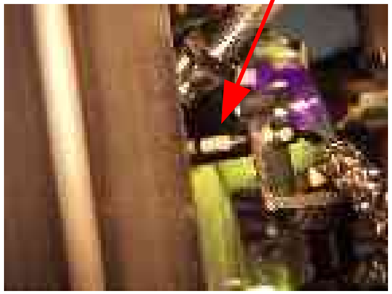
Pictures - 1

- Small Vacuum chamber used at LASTI for suspensions and coatings Q studies
- Co-opted to test new earthquake stops designed by Doug Cook, LHO
- Initial LIGO Pathfinder optic suspended in a full scale suspension frame.
- New earthquake stops seem to fit in the cage OK (1/2-13 thread is OK!)
- *Old stops are a bear to get out*

Pictures - 2



Rear view,
Position Sensor



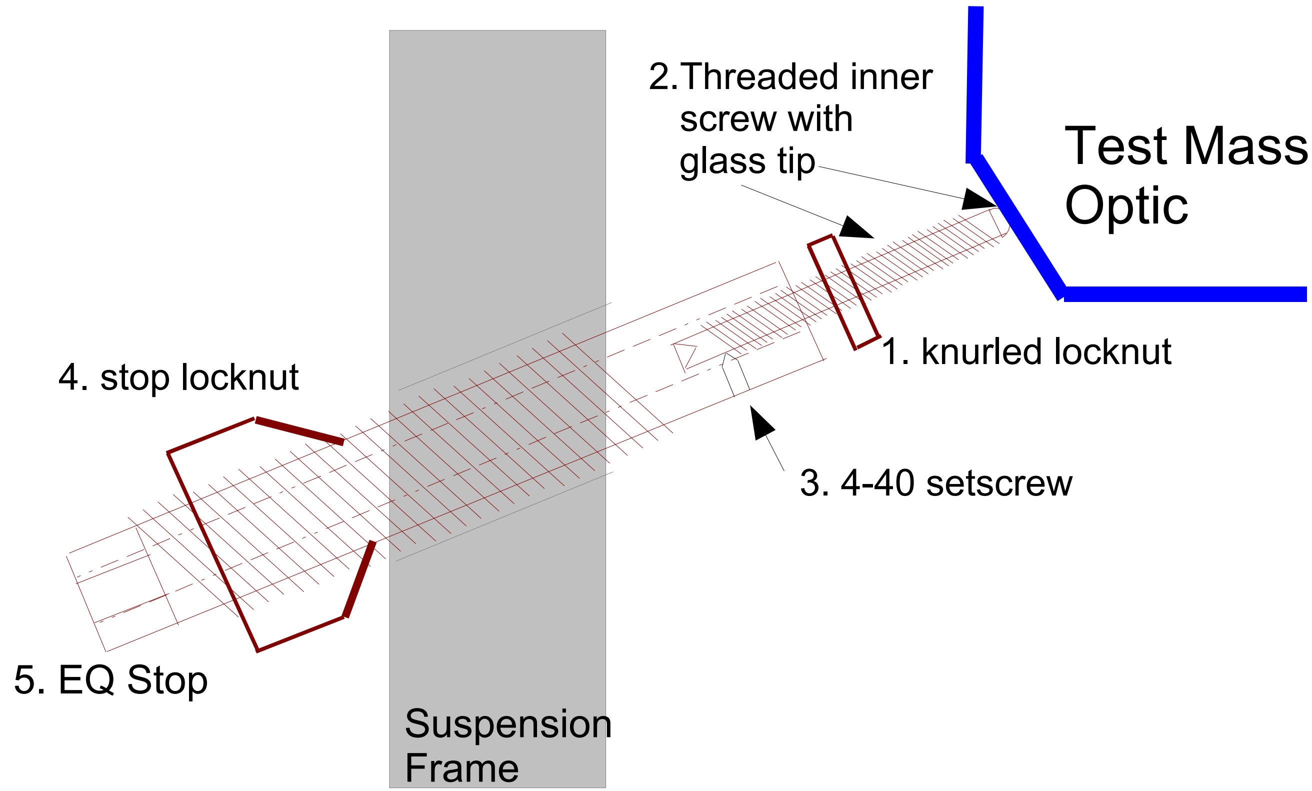
Suspended Optic

B & K Shaker

Slider

Procedure for inserting EarthQuake stops and Setting gap to 0.5mm

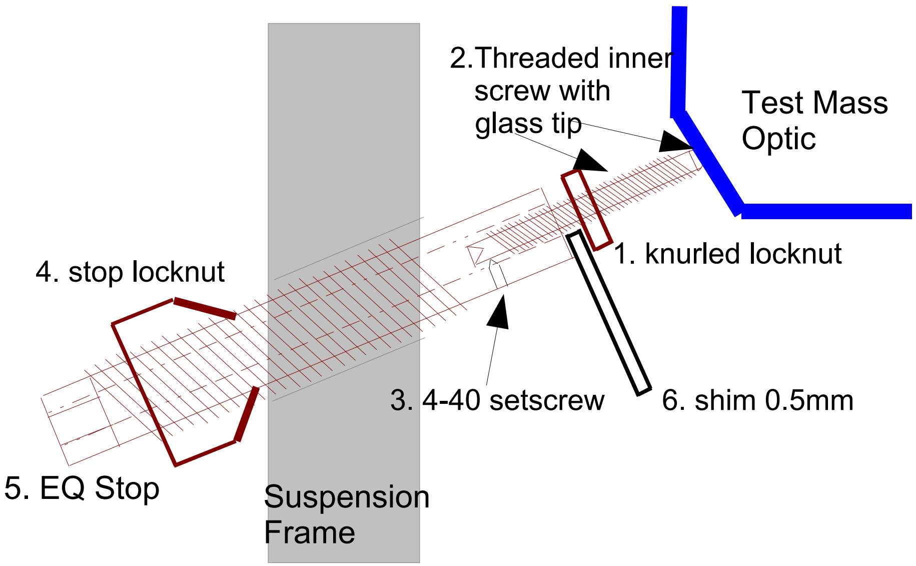
[1]



- (0) (preparation) Remove knurled locknut[1] from the inner screw[2]. Lock the inner screw[2] in place with a 4-40 setscrew[3] in the body of the EQ Stop[5], leaving about 3/4" sticking out. *One setscrew is sufficient.*
- (1) Screw in EQ stop[5] into socket on frame. Ensure that stop locknut[4] is screwed out on the body of the stop[5].
- (2) When the threaded inner screw[2] emerges out of the socket on the frame, thread the knurled locknut[1] onto it.

Procedure for inserting EarthQuake stops and Setting gap to 0.5mm

[2]

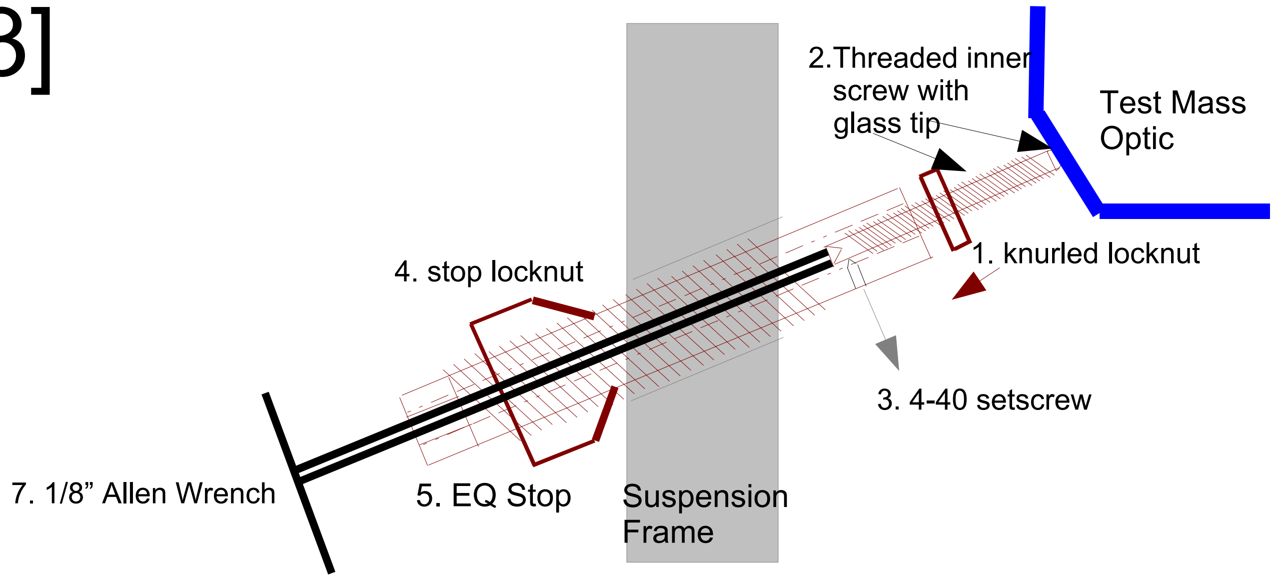


- (3) When the EQ stop[5] body emerges from the socket in the frame, the position of the knurled locknut[1] on the inner screw must be adjusted.
- (4) While the tip of the inner screw is still safely far away from the edge of of the optic, insert a 0.5mm shim[6] between the knurled locknut[1], and the front edge of the EQ stop[5]. Screw down the the locknut until it contacts the shim. Remove the shim.
- (5) Now thread the EQ stop[5] all the way into the suspension frame until the tip gently contacts the optic. Use the locknut[4] to lock its position to the frame

Repeat steps (0)-(4) for the other seven EQ stops. In the end, you have the optic held stationary pinned by the eight stops.

Procedure for inserting EarthQuake stops and Setting gap to 0.5mm

[3]



- (6) With the optic pinned in place by the eight EQ stops, go around and unlock the inner screws[2] on all of them by loosening the holding set-screw[3] for each.
- (7) Use a long 1/8” allen wrench[7] inserted through the hollow shaft of the EQ stop[4] to back out the inner screw[2] until the knurled locknut[1] touches the front edge of the EQ stop[5]. This sets the gap from the tip of the stop to the optic to be 0.5mm
- (8) Watch the optic swing free using the optical lever, as you release each stop and set its gap to be 0.5mm.

Results from impulses to the Suspension Frame

The following slides show results from various types of impulses applied to the suspension frame.

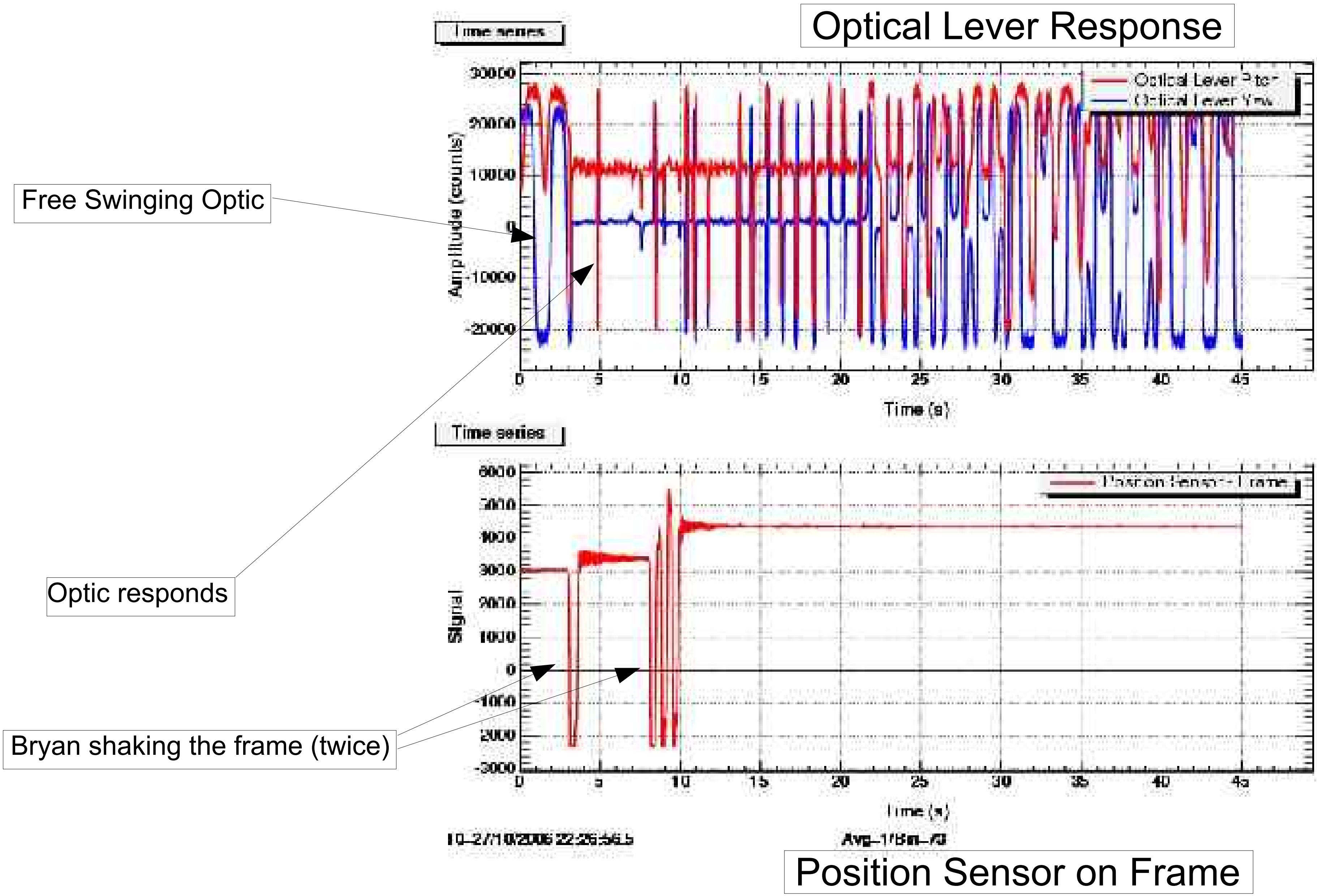
1) Movement of the frame back and forth on the sliders by hand

2) 400 second long signal recorded in LHO STS-2 seismomters from a magnitude 5.6 earthquake in Dillon, Montana, 05/07/2006 was used to excite the shaker attached to the suspension frame. The original signal data at 20 Hz was interpolated to 16,384 Hz to match the sampling rate of the excitation channel used.

3) A single impulse on the frame, and its effect on the optic. Two clear bounces are seen in the optical lever degrees of freedom.

4) The resonances of the optic suspension as measured by the optical lever, before and after the application of the impulse. No significant difference is seen in the two cases.

Manual Impulse to the Frame – 1

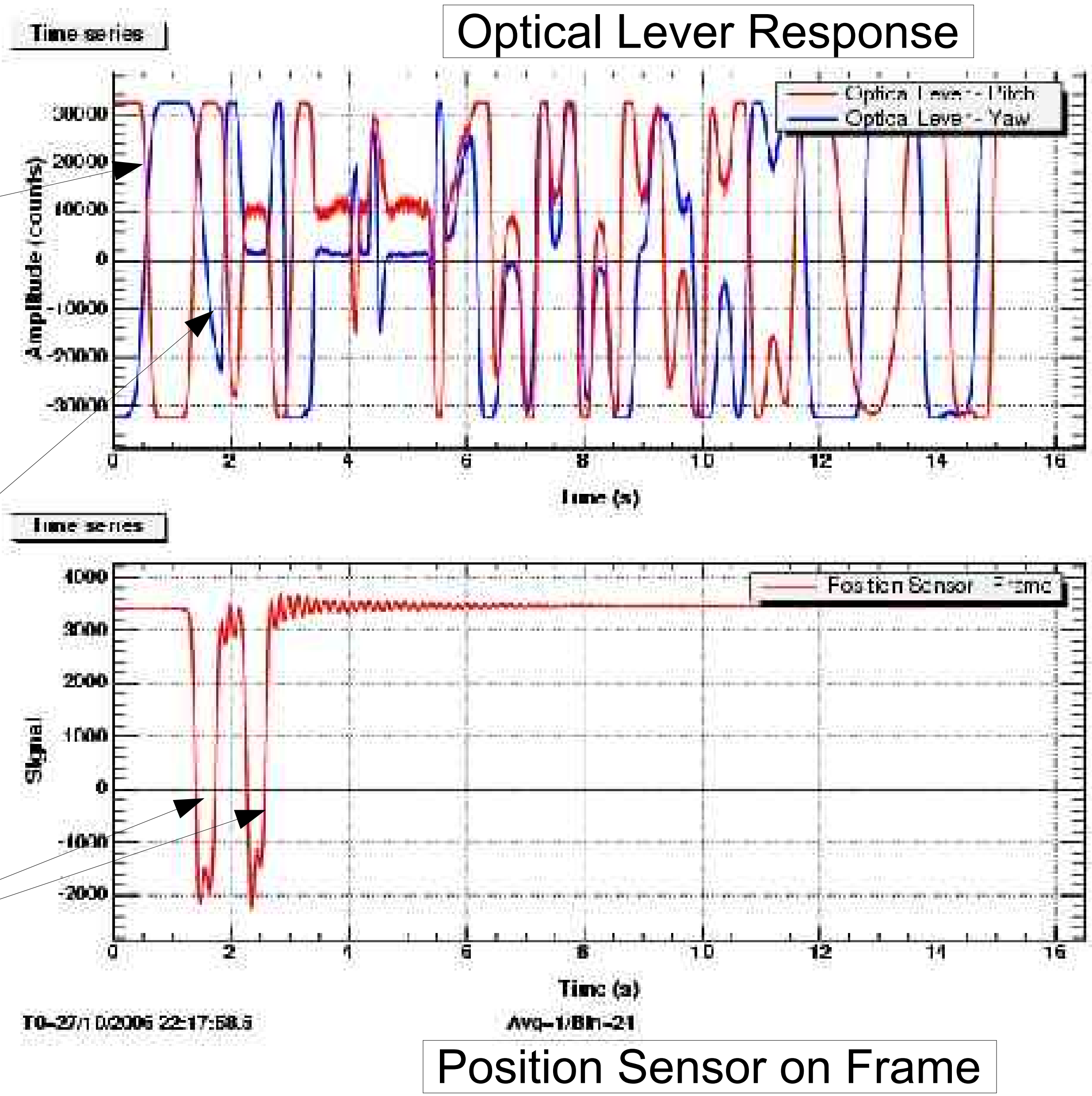


Manual Impulse to the Frame – 2

Free Swinging Optic

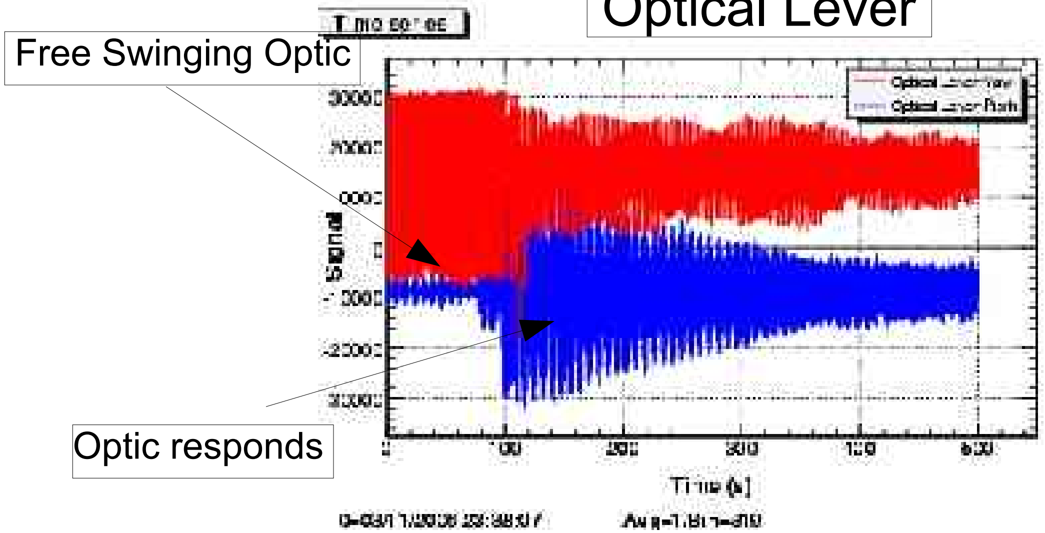
Optic responds

Bryan shaking the frame (twice)

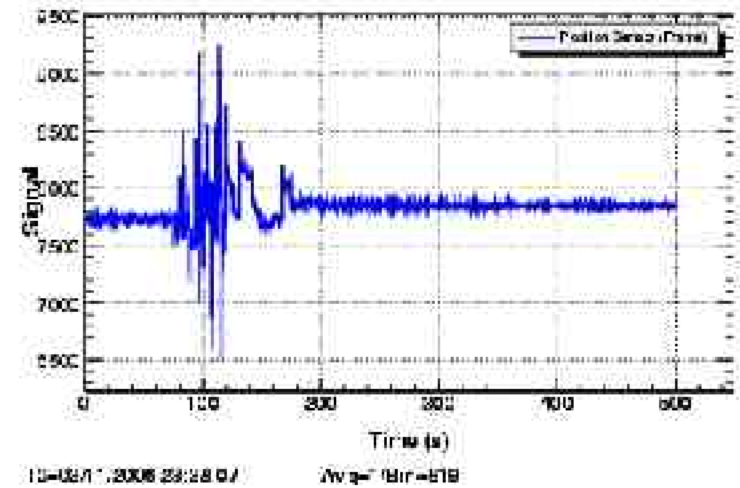


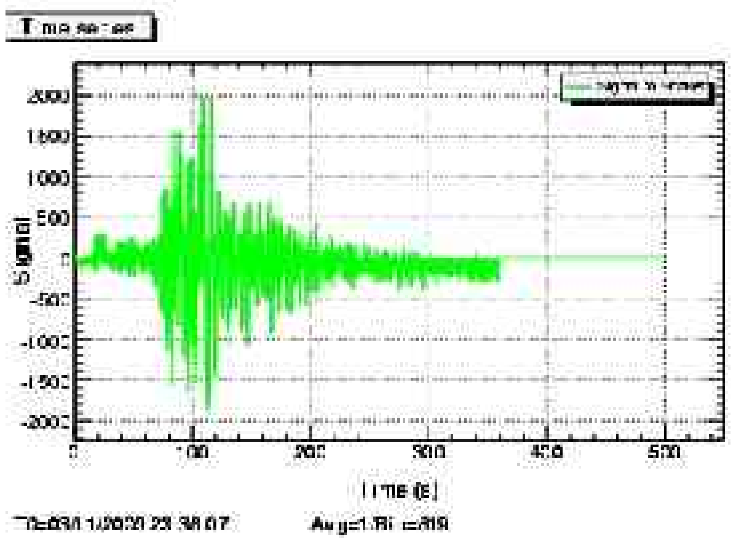
Earthquake signal data

Optical Lever

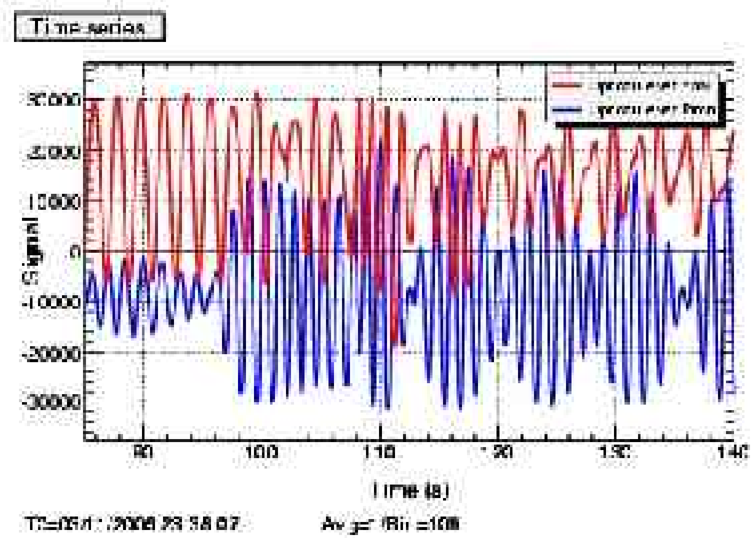


Position Sensor on Frame





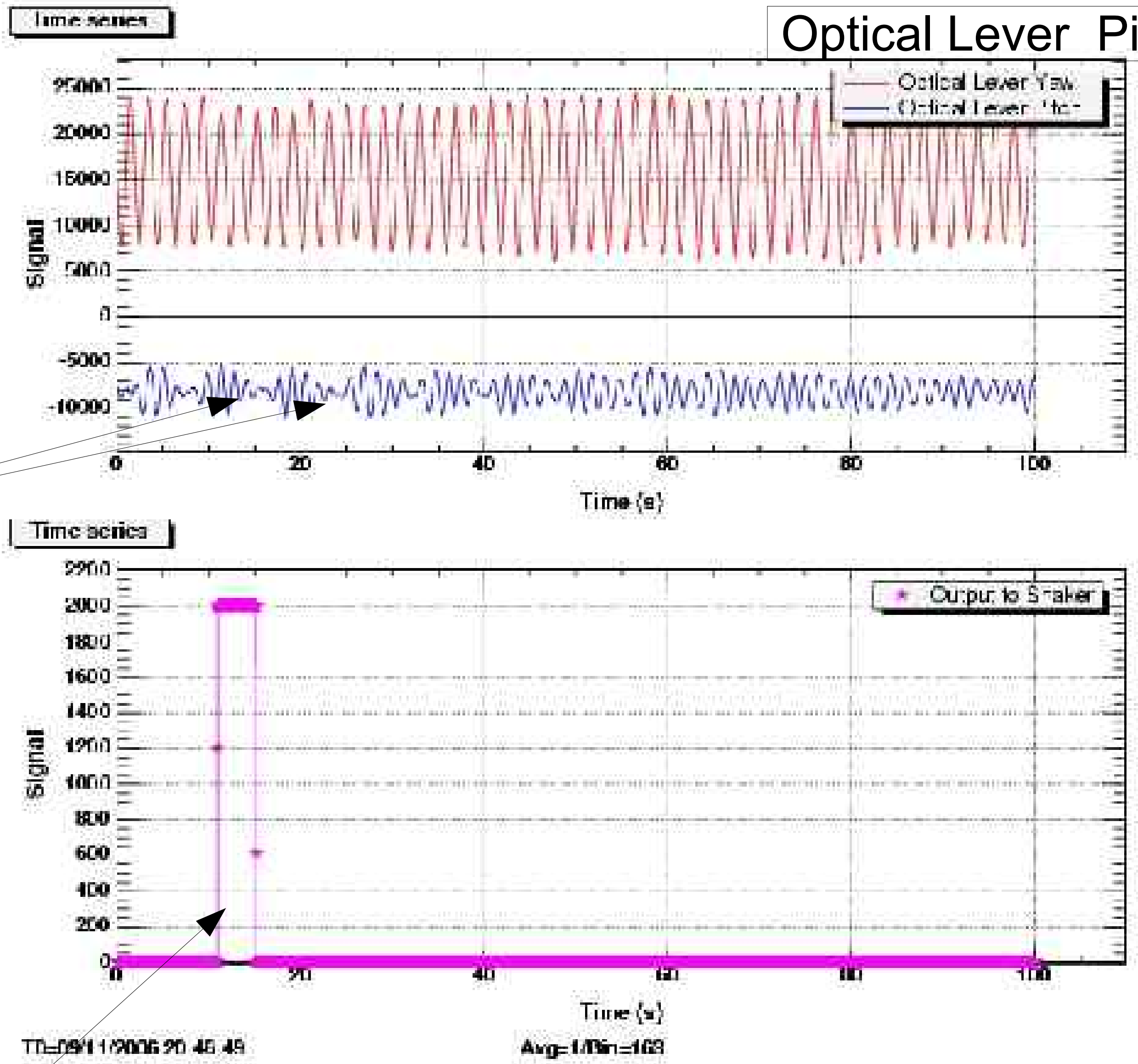
Excitation Signal to Shaker



Optical Lever Zoom

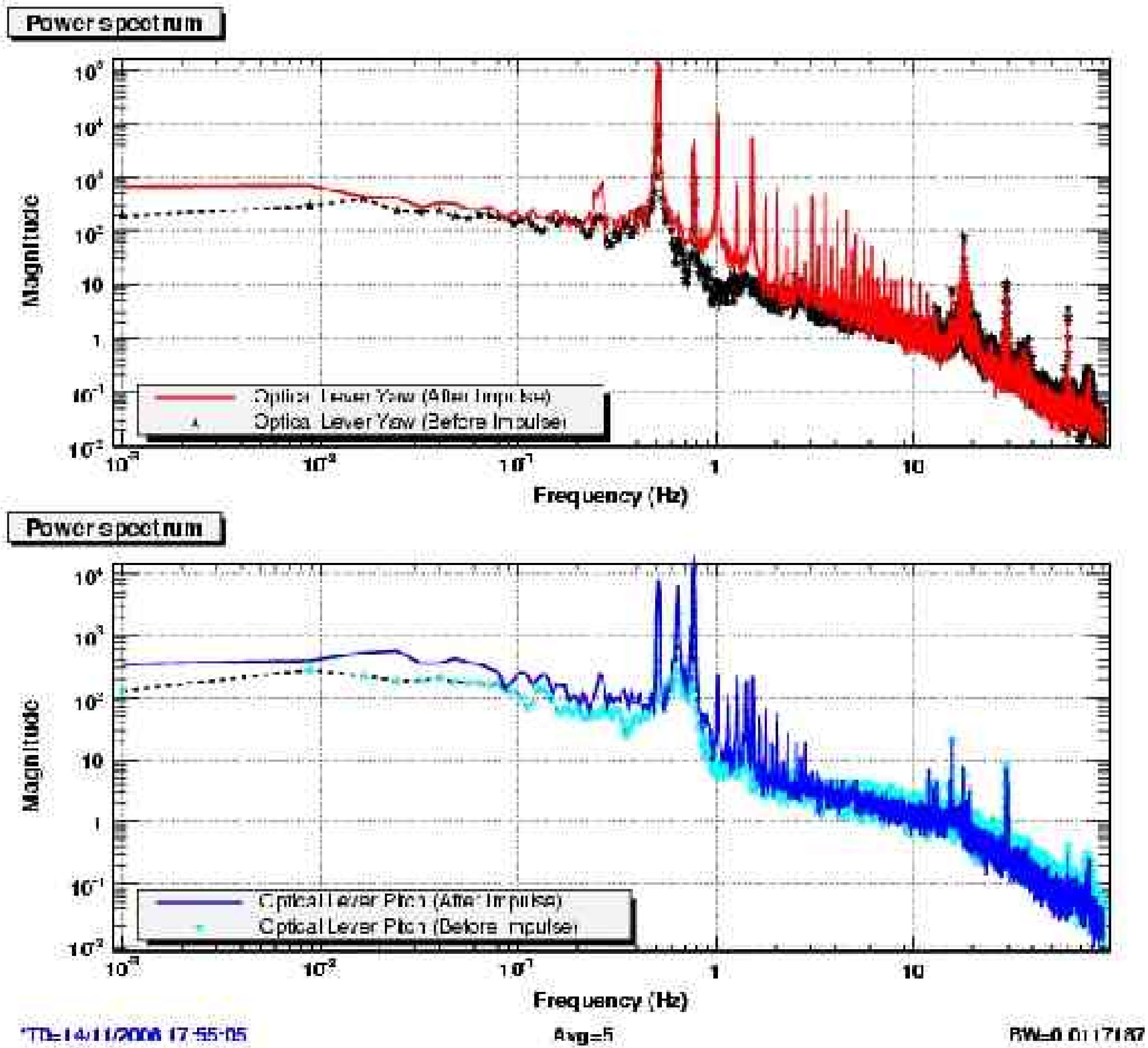
Compliance/Damping of Optic after single Impulse

Optical Lever Pitch & Yaw

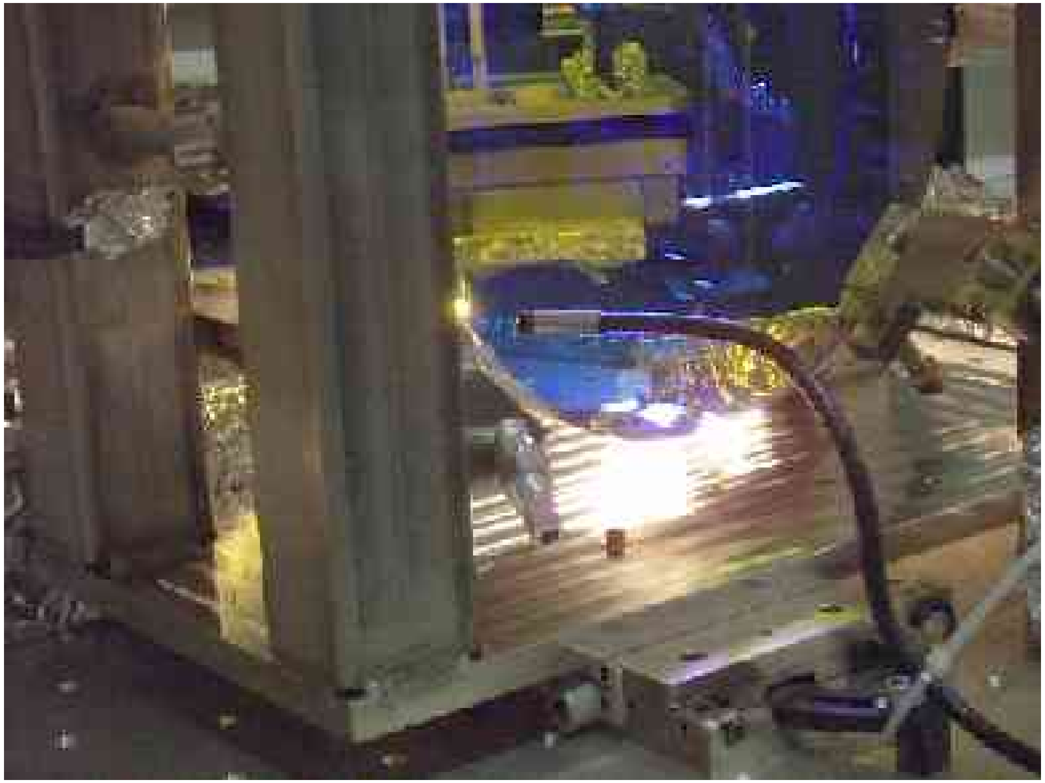


Excitation Signal to Shaker

Resonances – Before and After the Impulse



We like to watch!



Fiberscope aimed at point where the EQStop impacts the optic, imaged with handheld digital camera in video mode

Movies at:

MPEG http://ligo.mit.edu/~sarin/EQStop/WholeLottaShaking_1.mpg
http://ligo.mit.edu/~sarin/EQStop/WholeLottaShaking_2.mpg

QuickTime: http://ligo.mit.edu/~sarin/EQStop/WholeLottaShaking_1.mov
http://ligo.mit.edu/~sarin/EQStop/WholeLottaShaking_2.mov

Notes

- The glass tip bearing inner screw has fine 1/4-28 thread. Combined with the small size of the glass tip, this implies that the tolerance on where the tip contacts the optic is reduced.

- The glass tip is designed to impact the optic at a point that is laterally centered on it's chamfered edge. In our test setup, we tried to, but could not obtain this precise alignment, possibly as a combination of two things:
  1) The optic was not perfectly aligned within the frame. We had no OSEM's mounted on the optic, therefore the lateral positioning of the Optic at the time of suspension was accomplished by eye – mostly just a check that it's not grossly rubbing against anything.
  2) The cross members bearing the EQ stops were slightly misaligned from the rest of the frame. As mentioned previously, some the old viton tipped EQ stops were extremely difficult to extract from the frame. It's possible that excessive wrench force used during this step caused a slight bending of the

- In repeated dynamic testing, we observed no damage to the optic from impact upon the earthquake stops. The stops seemed to have enough compliance to damp the optic within two impacts.

- No effect was observed on the suspension resonances as a result of impacts on the EQ stops.

Conclusions

Objective	Results of Tests
• Mechanical fit check	+ The new EQ stops have the right mechanical design to be a direct replacement for the currently installed stops. -- The old EQ stops were rather difficult to extract from the frame. This may just be due to the fact that the frame was not very clean, and the stops were uncoated, raw steel bolts threaded into steel apertures
•Contact geometry	+ The new EQ stops have tips offering a much smaller contact area to the optic than the older stops which had a broad viton pad at their tips. This implies that positioning and alignment of the optic in the frame needs to be done with more precision, to get the stops to line up symmetrically along the chamfered edge of the optic.
•Compliance/Damping	+ In the tests performed at LASTI – the EQ stops demonstrate sufficient compliance to damp the optic within two bounces after impact. -- It was found that the glass bearing piston tip of the EQ stop fits too loosely in it's socket. It is captured and held in place by friction from a Viton O-Ring. Since a 'fatter' O-ring is not readily available, it is recommended that the o.d. of the piston shaft be increased, so that the fit at the tip of the EQ-stop is more snug.
Fine axial positionng	+ The EQ stops do offer sufficient ease and ability to set the gap to the optic at 0.5mm. We have described the procedure we used in this document.

Conclusions

Objective	Results of Tests
• Dynamic Testing	+ In repeated dynamic testing of the EQ stops, we did not observe any damage to the optic from repeated impact against the stops.
• Electrostatic charge buildup	+ The LASTI test setup was at air pressure (not in vacuum). We were therefore unable to test in any detail the build up of electrostatic charge from impacts between the optic and the EQ stops. + A close examination of the power spectra from the optical lever setup to observe the motion of the optic did not show any significant changes of the resonant modes before and after impacting against the EQ stops.

Summary:

1) The EQ stops seem to perform their function adequately. They constrain the optic's motion in the presence of violent external stimuli (like earthquake), and damp it quickly.

2) Within the capabilities of this test, we did not observe any changes in the resonances of the optic's suspension, as a result of impact on the EQ stops. This experiment was done at air pressure, so there was no expectation of an electrostatic charge buildup or effect on the resonances.

3) The lone concern regarding the mechanical design of the stops was the looseness of the glass bead bearing piston in its socket at the tip of the EQ stop. It is recommended that the o.d. of this piston be increased slightly, so that it fits more snugly in the tip. Else, there is a concern that over time, the piston would slip downwards closer to the optic in the EQ stops that are located in the upper quadrants of the suspension frames, pointing downwards towards the optic.