

LIGO ADVANCED SYSTEMS TEST INTERFEROMETER (LASTI)

Program Update:

LSC Meeting, LLO

Dave Ottaway for the LASTI team

March 2005

Talk Overview

1. Review of LASTI goals
2. Progress since August 04
3. Medium term detailed plans and general long term goals
4. Conclusions

LASTI Mission

- Test LIGO components & systems at **full mechanical scale**
- Practice installation & commissioning
- Minimize delays & downtime for advanced LIGO upgrades
- Qualify design modifications & retrofits for initial *LIGO*

Specific Advanced LIGO Program Tasks ('05 - '09+):

- Qualify advanced isolation & suspension systems and associated controls at full scale
- Develop detailed SEI/SUS installation & commissioning handbook
- Look for unforeseen interactions & excess displacement noise
- Test PSL and Input Mode Cleaner together at full power

LASTI People

Resident MIT Staff

- **Students** - Laurent Ruet (PhD student at INSA), Thomas Corbitt
- **Engineering** - Myron MacInnis, Ken Mason, Jonathan Allen
- **Scientists** - Gregg Harry, Rich Mittleman, Dave Ottaway, David Shoemaker, Pradeep Sarin, Mike Zucker (Advice)
- **Computers** – Keith Bayer

Laboratory and LSC Visitors (to date)

- **PSL Upgrades** – Rick Savage, Stefan Balmer, Paul Swinberg
- **Initial SEI & SUS**- Corey Gray, Hugh Radkins, Gary Traylor, Harry Overmier, Betsy Bland , Jonathan Kern, Marcel Hammond, Dennis Coyne

Laboratory and LSC Visitors (cont.)

- **Advanced SEI** - Joe Giaime, Brian Lantz, Wensheng Hua, Corwin Hardham, Samir Nayfeh and Lei Zuo
- **Advanced SUS** - Norna Robertson, Calum Torrie, Janeen Romie, Phil Willems, Justin Greenhalgh, Ken Strain, Caroline Cantley, Mark Barton...
- **CDS/DAQ** - Jay Heefner, Rus Wooley, Paul Russel...

Since the Last Review

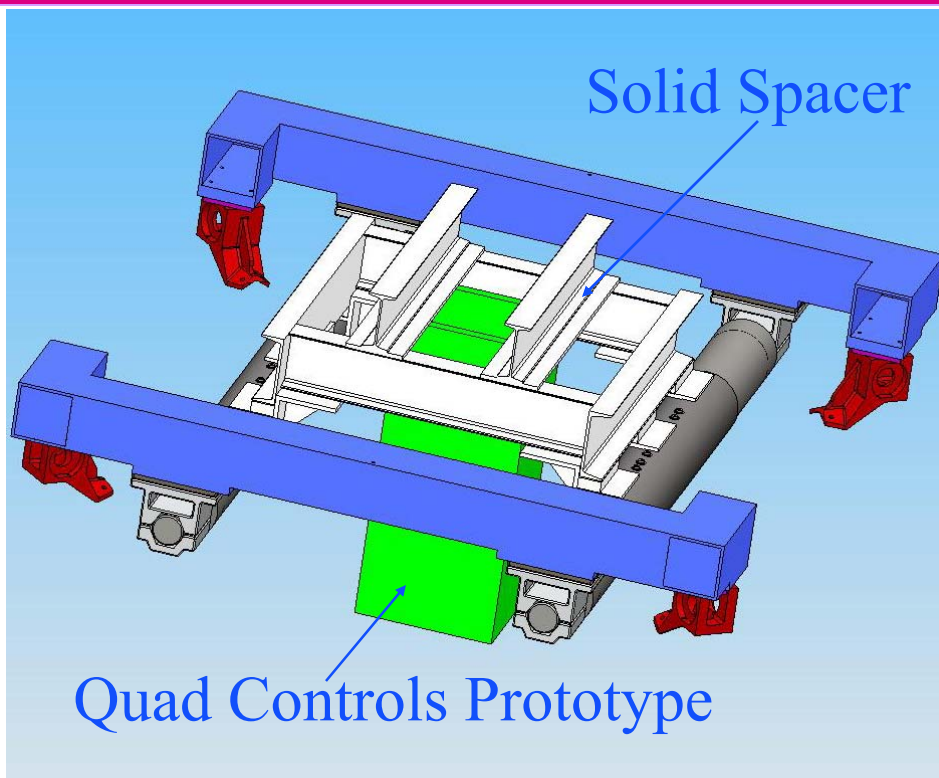
- Infrastructure
 - » Prepare highbay for assembly of full scale seismic/suspension testing
 - » Control room now operational and functional
- Triple prototype characterized using the HEPI platform as a shake table.
- Further investigations on the HEPI system
 - » See talk by Richard Mittleman, in SWG session this afternoon
- 10 Watt Lightwave laser saturation study
- Planned response to further BSC seismic delays
- Ken Mason now lead engineer for Advanced LIGO Seismic (replacing Larry Jones)

Infrastructure Development

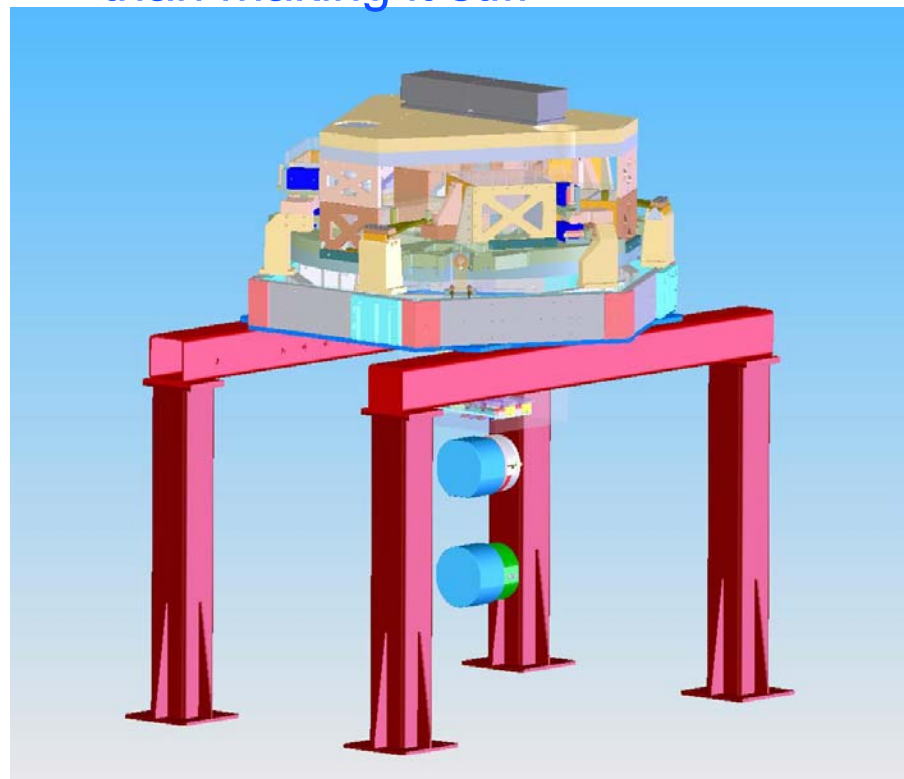


- Control room now operational
- Dome stand in place
- Design of Test Stand (Near Complete)
- Evolving the PSL into a user facility
 - » Now allows multiple experiments
 - » New Tabletop FSS Installed (Thanks Rick S, Paul S and Stefan B)

Infrastructure Development (2)

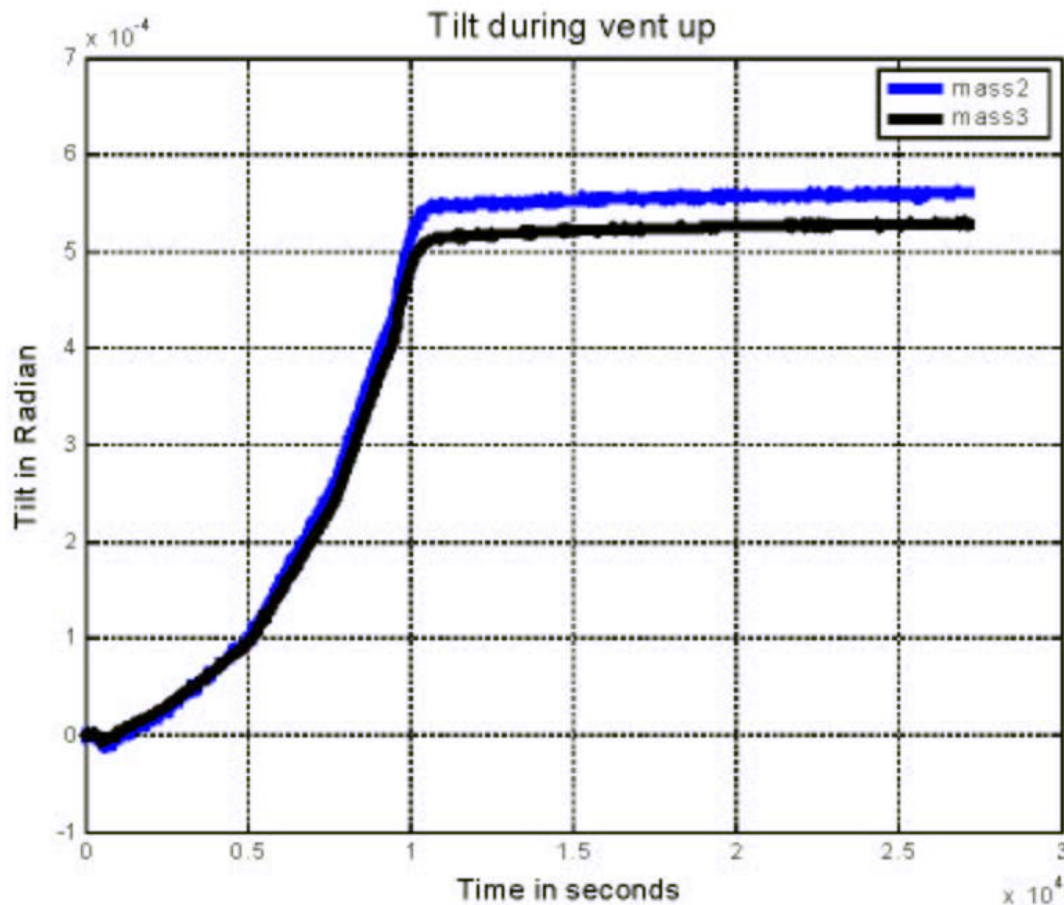


- Test stand design almost complete
- Designer floppy, more difficult than making it stiff



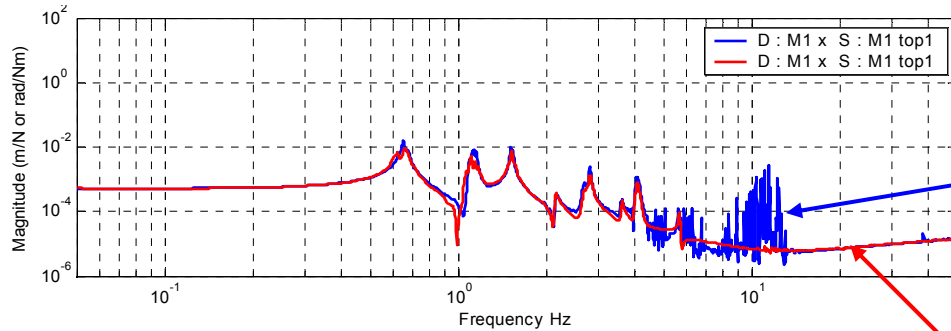
- Solid spacer design is complete
- First resonance ~ 50 Hz
- Enables Quad testing to be schedule independent of SEI

Significant Tilts with vacuum chamber pump out

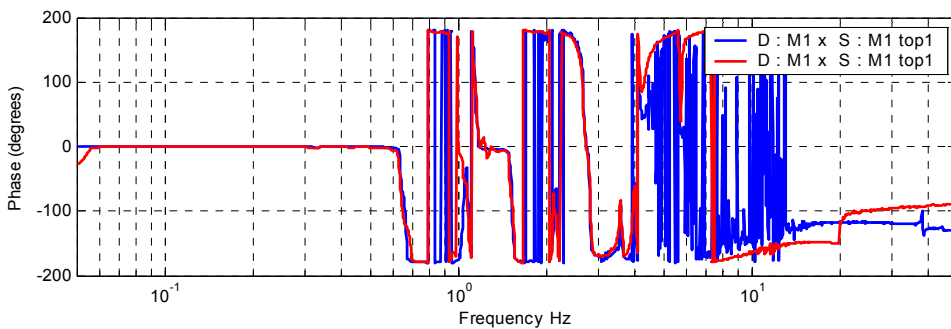


- Unbalanced atmospheric pressure forces on vacuum chamber tilts the floor
- Tilt is greater than the range of HEPI
- Suspensions are tilted greater than the OSEM range (Particularly Quads and Triples)
- Optical tables need to be set with this in mind

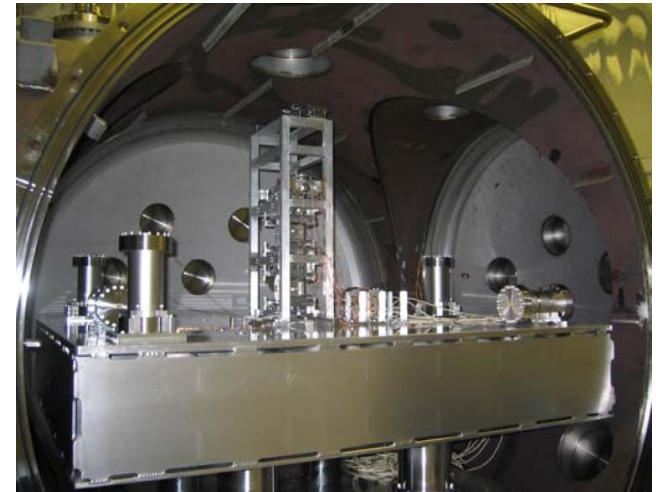
MC Triple prototype testing in LASTI



No noise reduction, HEPI system resonances create noise at 7,9,12 Hz



Noise reduction

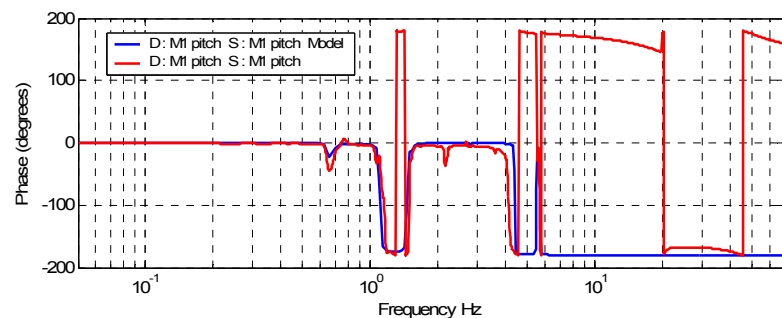
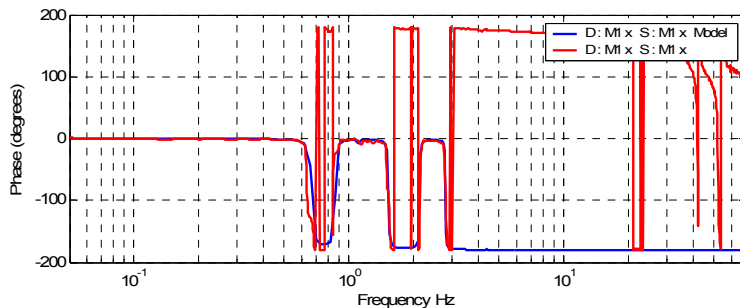
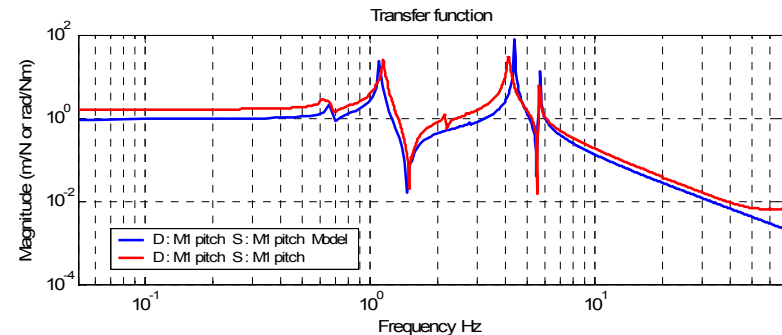
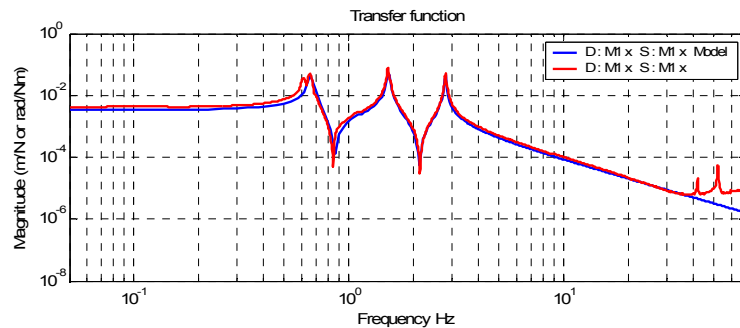


Noise reduction method to get rid of HEPI resonances noise

- » Sensing the ground and remove the coherent part
- » Help to study cross coupling and weak transfer functions

Additional MC Prototype results

- Good match with the model
- 3 problems solved (or almost)
 - » Roll transfer function, corrected thanks to mark's model
 - » Pitch transfer function, bottom wire parameter was wrong in the model
 - » Frame resonance, resonances at 41 and 52 Hz seem to be optical table resonances



HEPI and Advanced Seismic LIGO Development

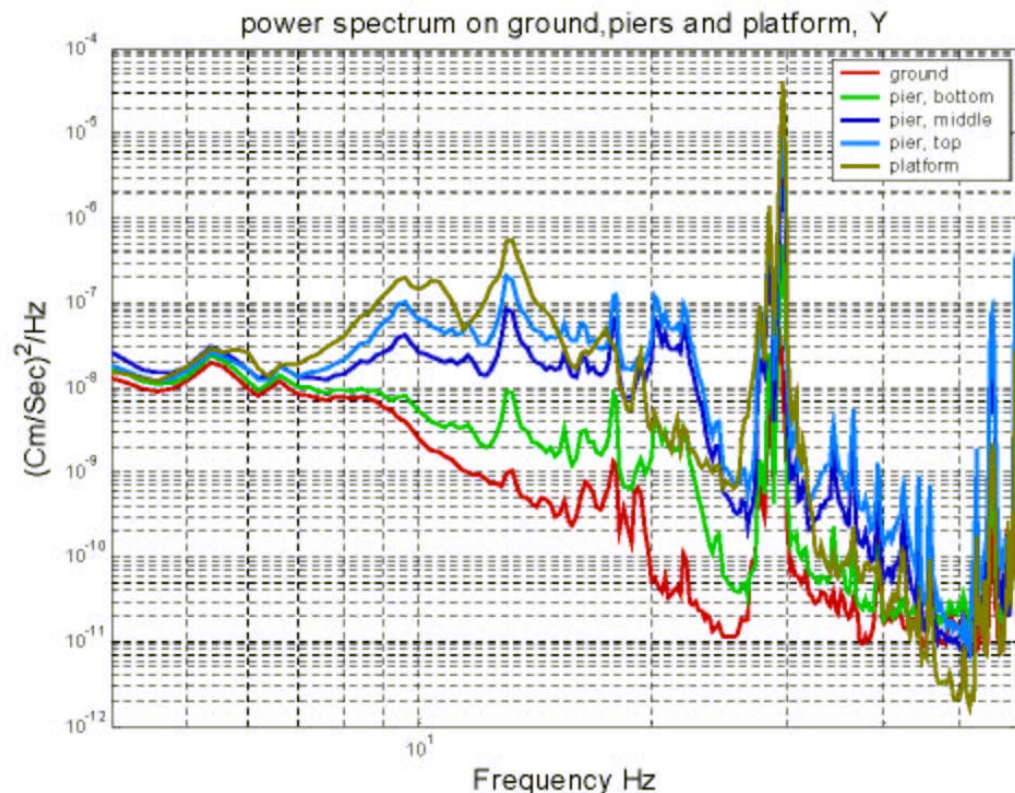
HEPI Development

(See Talk by Rich M)

- Sensor correction for Tilt modes
 - » Allows lower blending of the Geophone and Position Sensor
- Amplitude dependent transfer functions
- Studies of HAM structure bending

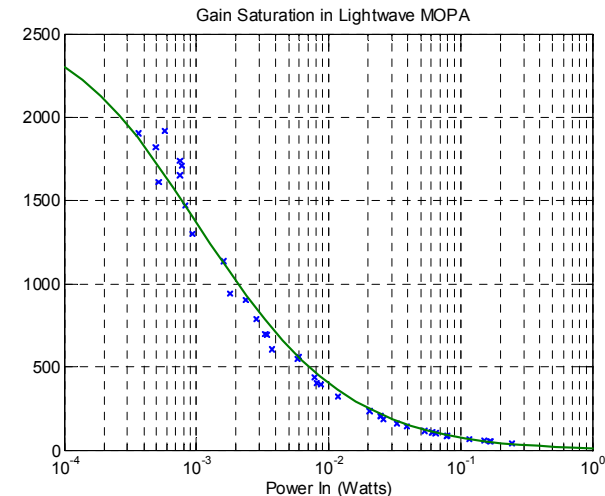
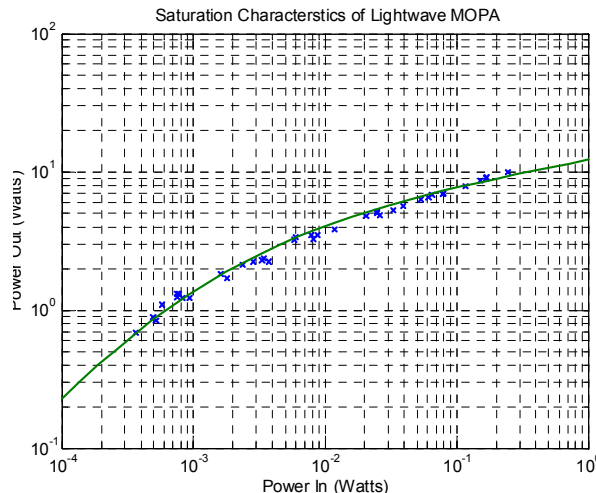
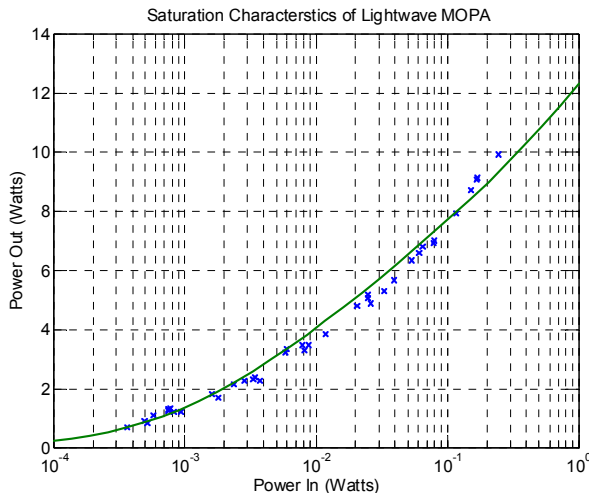
Advance LIGO Seismic Development

- Investigate excess noise at top of piers with mock Advanced LIGO stage zero
- Remove springs and masses, and support optical table from underneath
- Framework in house and currently being installed
- Stay tuned for results



Lightwave 10 Watt Laser Study

- Investigate the saturation characteristics of our Lightwave 10 Watt laser to validate model
- Study means of increasing the output power to 30 Watts and still fit within existing LIGO infrastructure



Small Signal Gain = 3800, PA current = 22 A, Average spot size = 0.33 mm, Rod diameter = 0.84 mm

Scatter loss per rod = 1.5 % , Max power extraction = 13.5 W Power In = 100 W

Lightwave 10 Watt Laser Study (2)

$$\frac{dI(x)}{dx} = \frac{g_0 I(x)}{1 + I(x)/I_s} - \alpha(x)I(x)$$

Where: g_0 is the small signal gain coefficient

α_0 is the loss coefficient, I_s is the gain medium saturation coefficient

This equation is transcendental equation and needs to be solved numerically

Turn this differential equation into a difference equation



$$I_{forward}(x_j, t_n) = I_{forward}(x_{j-1}, t_{n-1}) + \frac{g_0 \Delta x I_{forward}(x_{j-1}, t_{n-1})}{1 + (I_{forward}(x_{j-1}, t_{n-1}) + I_{backward}(x_{j+1}, t_{n-1}) / I_s)} - \alpha I_{forward}(x_{j-1}, t_{n-1})$$

$$I_{backward}(x_j, t_n) = I_{backward}(x_{j+1}, t_{n-1}) + \frac{g_0 \Delta x I_{backward}(x_{j+1}, t_{n-1})}{1 + (I_{forward}(x_{j-1}, t_{n-1}) + I_{backward}(x_{j+1}, t_{n-1}) / I_s)} - \alpha I_{backward}(x_{j+1}, t_{n-1})$$

LASTI Schedule for Advanced LIGO

Controls Prototype

- Jan '05 Design and fabricate Solid Spacer for BSC
- Jun '05 Assembled Quad arrives and external shakedown begins
- July '05 Cartridge installed into vacuum
- Oct '05 Preliminary locking tests begin
- Jan '06 Removed from vacuum

BSC Seismic Development

- Mar – Aug '05 Procure parts
- Oct '05 Dirty assembly
- Nov '05 Modal testing
- Nov '05 Disassemble
- Dec '05 Clean parts
- Jan '06 Clean assembly
- Mar '06 Pre- installation test
- May '06 Vacuum installation
- Jun '06 Removal from vacuum

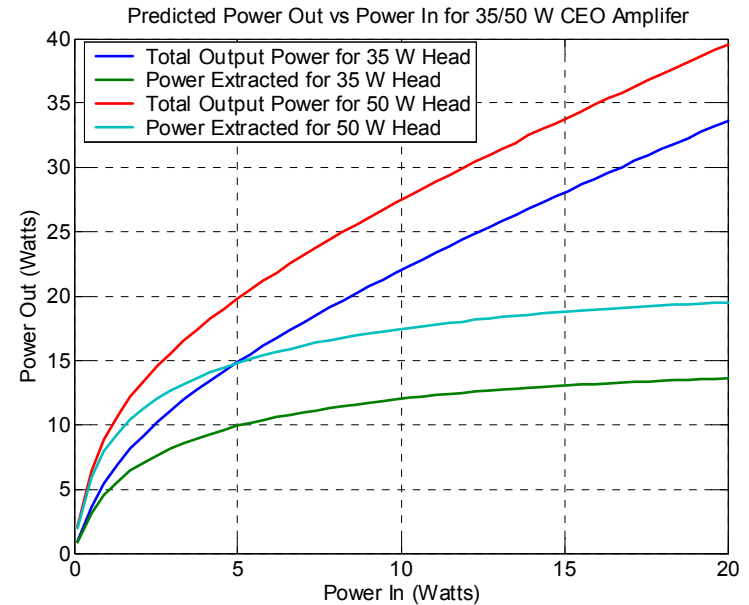
Jun '06 Combine Quad and BSC Extra-Vacuum

Jul '06 Cartridge Install

Other LASTI Use

- PSL
 - » Testing of power upgrade stage for Initial LIGO
 - » Laser source for the Pondromotive squeezing experiment
 - » Dedicated LASTI use not required for a significant period of time

- Yend HAM
 - » Soft suspension for possible use in isolation of Initial LIGO output mode cleaner
 - » Designed by Riccardo Desalvo
 - » Qualification tests should be conducted at LASTI before installation at the observatories
 - » Need additional manpower to resource this if this is to be completed by start of 2007 for installation Post S5.
 - » Decision on requirements from Daniel Sigg



LASTI Schedule (Longer Term)

2Q05: Quad controls prototype

2Q05: BSC SEI pathfinder installed for standalone testing

4Q05: HAM SEI pathfinder installed for standalone testing

1Q06: LASTI noise test begins; SUS prototypes installed

3Q06: Interferometric displacement tests

4Q06: Thermal compensation integration and test

1Q07: LASTI SUS/SEI test review

3Q07: Adv LIGO PSL/MC tests start (180 Watts)

Depends on review seismic review panel decision

Depends heavily on available funds

Conclusions

- Significant progress has been achieved
- Work around solutions have been found to maximize progress given external delays
- Anxiously await the seismic review panel decision to enable the start of construction of the Advanced LIGO Seismic prototype for LASTI
- We will be ready to accept the Controls Quad Prototype in June '05

LASTI Detailed Optical Layout

