LIGO Laboratory R&D for the period Fall 2007 to Fall 2008

Presented at the MIT MOU Review

16-17 August 2007

Outline

- Lasers
- Optics
- Suspensions and Isolation
- Interferometer Configurations

AdLIGO PSL R&D - Peter King

- Develop a low-noise, vacuum compatible photodetector
  - 100mA of photocurrent
  - bandwidth of at least 1MHz
  - materials and component vacuum qualification
  - vacuum compatible fabrication techniques
  - reliability qualification
  - thermal management
- Make progress towards demonstrating the AdL PSL RIN requirement at 10 Hz, namely 2×10^{-9} / Sqrt[Hz]

Outline

- Lasers
- Optics
  - Core Optics
  - Optics Testing and Specification
  - Modeling and Simulation
  - Auxiliary Optics Systems
  - Thermal Compensation System
  - Thermal Noise
- Suspensions and Isolation
- Interferometer Configurations

Core Optics - GariLynn Billingsley

- Demonstrate TM polishing ability at Third Vendor
- Develop FM/BS polish/coating strategy to ensure flatness
- Check the effect of high temperature annealing on optical figure
- Check the effect of Magneto Rhealogical Finishing (MRF) on surface scatter and absorption
- Investigate and properly attribute the scatter observed in initial LIGO

Optics Testing and Specification - Bill Kells & Liyuan Zhang

- RTS (Reflection, Transmission & Scatter)
  - » Improve integrating sphere scatter sensitivity
  - » Further improve absorption scan sensitivity
- Investigate in situ scatter calibration vs cavity loss
- BRDF (angle resolved) scatterometer bench & compare
- Point Scatter
  - » Develop direct scatter [camera] imaging in Optical Testing Facility (OTF) at Caltech
  - » Better distinguish/characterize "point defects"
    - Is it mostly "dust" (or: surface component vs embedded component)
- Coated optic 1064 nm phase front profilometer
  - » Direct determination of coated optic micro-roughness
- Direct calibration (via standard) of 1064 nm HR mid scale (~mm) roughness.

Modeling and Simulation
- Hiro Yamamoto

- Static Interferometer Simulation (SIS)
  - » Code development to simulate the full advLIGO
  - » Analysis of thermal effects in TCS design
  - » Complete analysis for COC design requirement
- End to End time domain simulation (e2e)
  - » Lock acquisition
    - High power including radiation pressure
    - Robust lock acquisition strategy
  - » Code development for the fast simulation of the dual recycling Michelson cavity using modal model

AOS R & D - Mike Smith

- BRDF Measurements
  - super-polished window
  - black glass
  - oxidized stainless steel
  - HR mirror surfaces
- Baffles
  - Arm Cavity Baffle
  - Elliptical Baffle
- AOS Suspension Damping Test

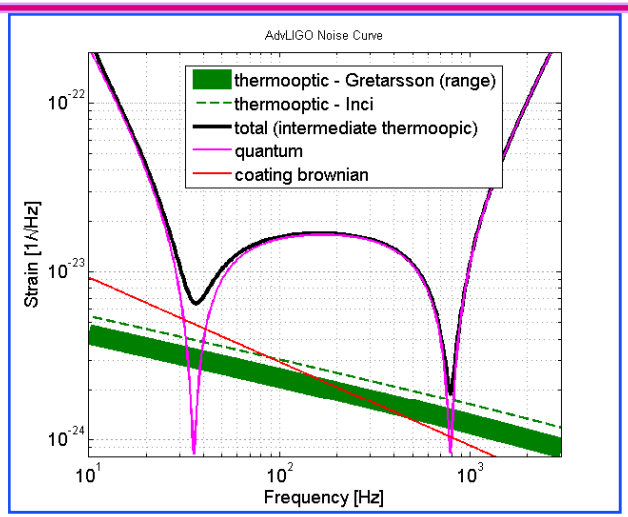
Thermal Compensation and Photon Calibrator Research - Phil Willems

- Characterization of absorption in initial LIGO optics
- Upgrade TCS for Enhanced LIGO
  - » Laser intensity stabilization for reduced noise injection
  - » Axicon optics for more efficient power delivery
- Upgrade Pcal for final S5 calibration and improved Enhanced LIGO calibration (improve power characterization)

Thermal Noise: Coatings - Gregg Harry

Focus on Coating Research

- Written plan involving Lab and LSC
- Work with LSC and multiple vendors to try new coating materials and techniques
  - » Hafnia, alumina, titania-tantala-silica, ziconia
  - » SiO_2 thin films
- Q measuring to be done in Lab for some samples (others elsewhere)
- Direct thermal noise on selected samples - TNI



Coordination and Samples

- Most coating samples and runs will be provided to LSC by Lab
- Overall research direction and logistics provided by COC Team
  - » Research plan divided into AdvLIGO development (mostly in Lab) and research for future (mostly in LSC)

TNI and Thermal Noise - Eric Black

- Broadband noise measurement in optimized, aperiodic, undoped silica-tantala coatings
  - » Model validation of Benevento genetic method
  - » Independent measurement of thin-film silica loss, currently not well known
- Broadband noise measurement in optimized, doped coatings
- Direct, broadband measurement of thermo-optic noise
  - » Collaboration with Andri Gretarsson
- Measurement of thermo-mechanical properties of doped coatings, aperiodic coatings
  - » Photothermal apparatus
  - » Separates thermo-mechanical effects from thermo-refractive ones
  - » Compliments dn/dT measurements at ERAU
- Continue ring-damper work

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SEISMIC ISOLATION - Ken Mason

- The current SEI work is focused on the interferometer upgrade.
  - The design, fabrication and testing of the HAM ISI (Internal Seismic Isolation) system is fast tracked to meet the Enhanced LIGO schedule.
  - Construction and procurement is well underway with an initial construction and testing phase scheduled to take place at the HPD facility in Boulder Co.
  - The first commissioning will take place at Hanford followed by more extensive work at MIT on the third platform.
- The BSC ISI is being reassembled in a vacuum compatible fashion at MIT. It will be mated to the Quad-noise prototype soon and the entire assembly will be tested in the LASTI vacuum system.
- Once the SEI systems are understood, a cavity will be formed between suspensions on those platforms as an integrated test
- These activities will be intensive through most of 2008.

Suspensions work in LIGO - Norna Robertson

- Development of multiple pendulum suspensions for Enhanced and Advanced LIGO
  - **Test mass quadruple pendulum:** UK GEO group responsibility in collaboration with LIGO. Noise prototype currently being assembled at LASTI. Full program of tests, including joint tests with ISI, in 2007/2008. Controls prototype cavity tests will finish when noise prototype ready for installation
  - **Output modecleaner double pendulum:** currently undergoing tests at Caltech. Two suspensions due to be installed and commissioned for Enhanced LIGO over next 12 months
  - **Recycling mirror triple pendulum:** currently in detailed design phase. Prototype to be constructed at Caltech. Preliminary testing at Caltech prior to delivery to LASTI for further tests, scheduled for early 2008.
  - **Beamsplitter triple pendulum:** detailed design starting in UK - LIGO lab supporting development.
  - **Input modecleaner triple pendulum:** modest redesign work and final prototype scheduled for late 2008.
- Investigation of excess noise in clamps and stand-offs
  - Study of LIGO-1 clamp and stand-off design (MIT with HWS group). Has potential application to Enhanced LIGO and for wire suspensions in Adv LIGO

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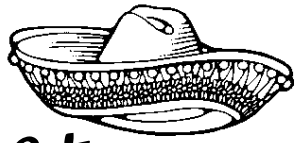
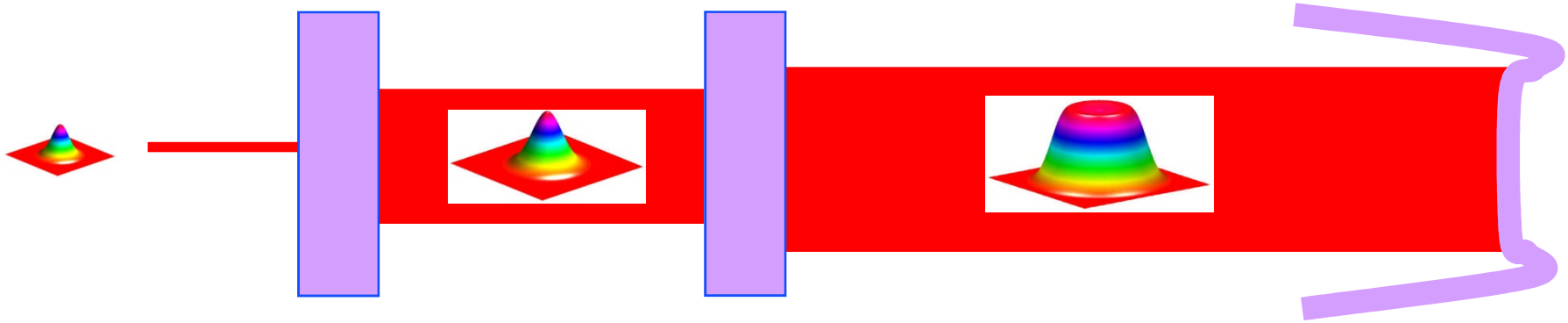


Mesa Beams - John Miller

- Wavefront sensing
  - » alignment tolerances of mesa beams are predicted to be slightly more stringent than Gaussians
- Three mirror coupled cavity
  - » interaction of Gaussian and non-Gaussian cavities
  - » alignment & locking signals
  - » coupling efficiency
  - » applications to power and signal recycling

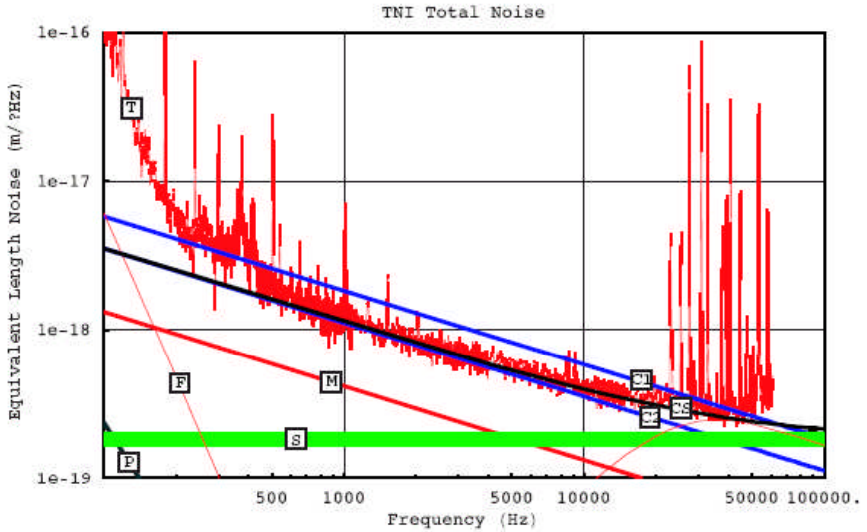


Extra Overheads

Thermal Noise Interferometer

Coating Thermal Noise Issues

- Directly measure thermal noise on selected coating samples
  - » Optimization of thicknesses in tantala/silica
  - » Silica-titania/silica as AdvLIGO backup
  - » Look for thermo-optic noise
  - » Other coatings as developed and look promising
  - » Final AdvLIGO coating check (likely optimized titania-tantala/silica)
- Try to measure coating thermal noise versus beam spot position
  - » Test of coating homogeneity
- Look for thermo-optic noise in existing data
- Thermoelastic parameters in Rao apparatus
  - » Coefficient of thermal expansion and thermal conductivity

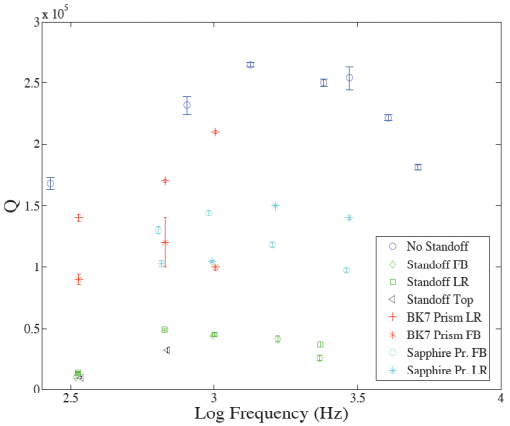


Other Issues

- Modeling and calculations to see practicality of seeing other noise sources
  - » Charging Gaussian noise, suspension thermal noise
- Examine non-Gaussian noise in data
  - » Try to isolate source

Suspension Thermal Noise in Initial and Enhanced LIGO

- Measurements (both t and f domain) at sites show Q's worse than expected from wire material properties and variable for a given mode
  - » Likely due to rubbing friction
- Experiments at MIT and HWS indicate rubbing is at standoff and not at the clamp
  - » Possible clamp is a lesser effect being masked by standoff
- Recent results show improved Q's with a BK7 prism standoff
  - » Only for wire motion perpendicular to beam
  - » At material limit at higher frequencies, near it at low frequencies



Future Plans

- Evaluation of groove made in prism
  - » Laser cutting, wire saw
  - » Effect on Q, effect on optic hanging
- Different standoff materials
  - » Silica, sapphire
- Examine metal ribbons to reduce dissipation dilution factor
- Test whether changes to clamps