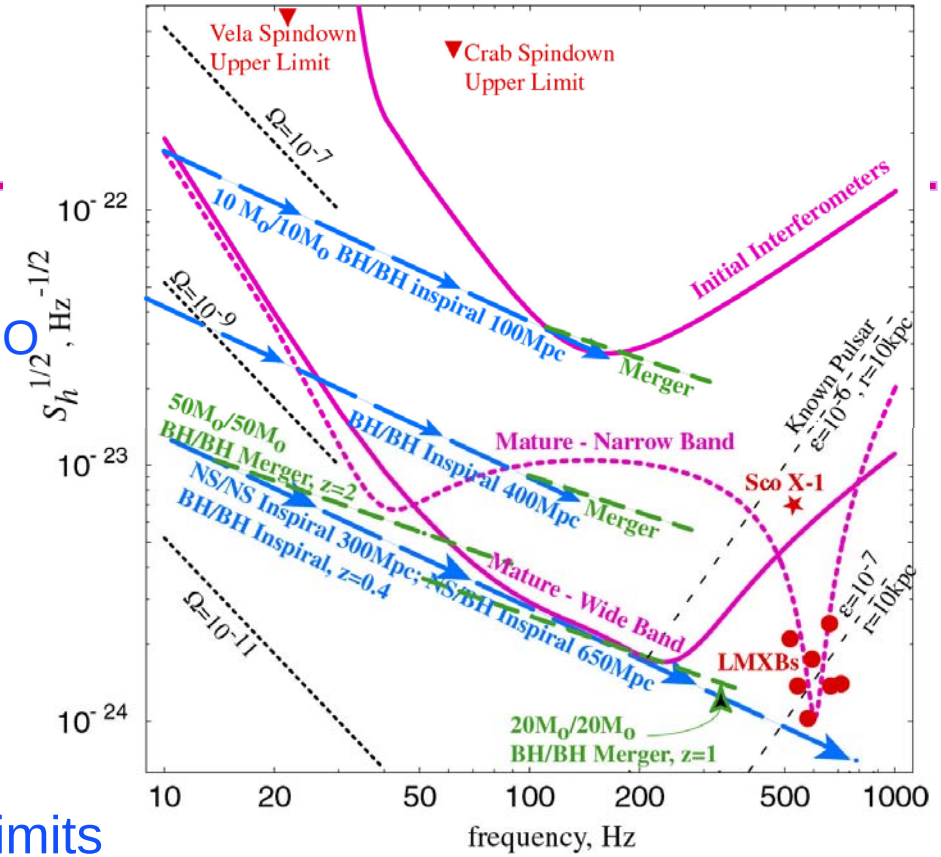
Advanced LIGO Update

David Shoemaker

LSC LHO August 2005

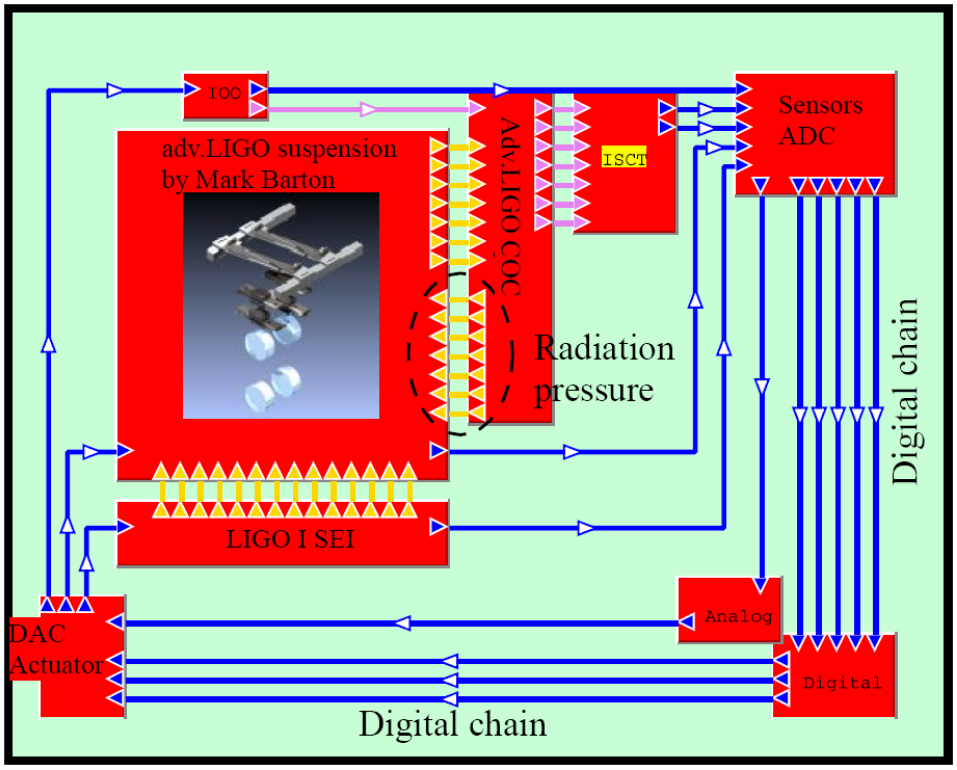
Advanced LIGO

- If you have been on vacation...
  - » Second generation of detectors in LIGO
  - » ~Factor 10 in amplitude sensitivity
  - » ~Factor 4 lower frequency
- Quantum Limited
  - » Recombined Fabry-Perot Michelson
  - » ~20x higher input power
  - » Signal recycling → tunable
- Gravitational gradient, thermal noise limits
  - » 40 kg fused silica masses
  - » Fused silica suspension
  - » Active seismic isolation



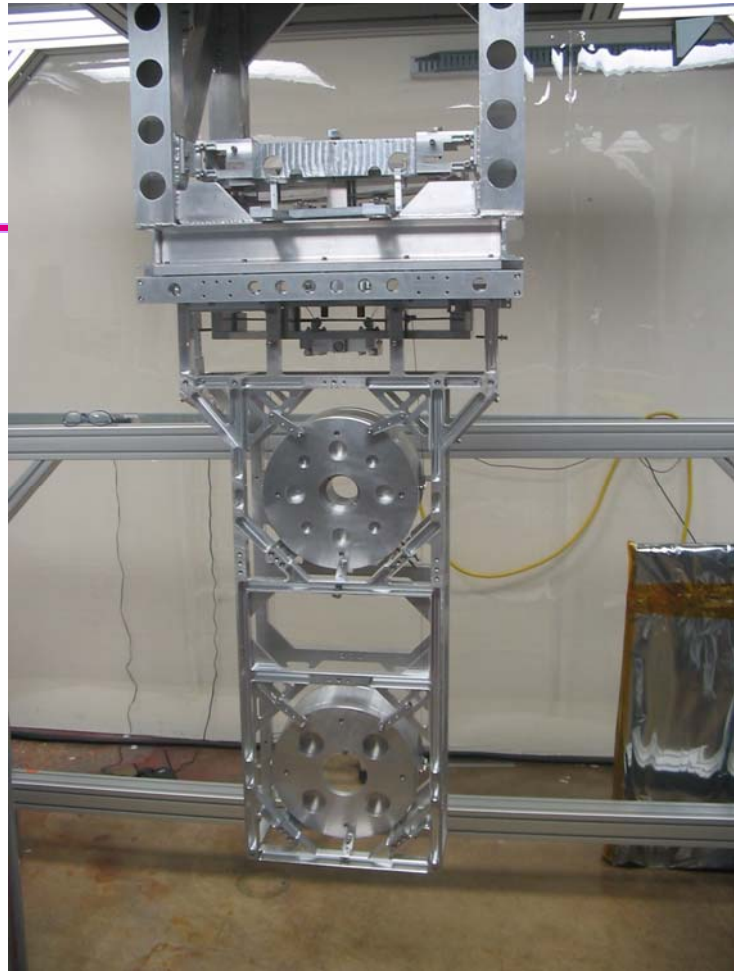
- ….and now: a quick run through of progress highlights and active questions

Systems

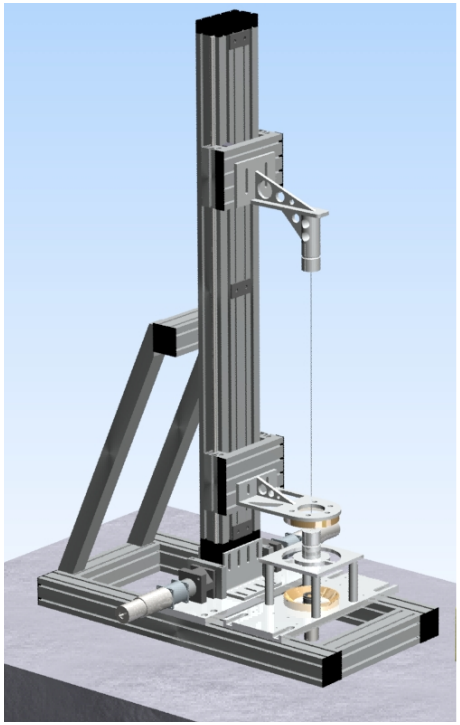


- e2e for Adv.LIGO: All ingredients to build now available
- Simulation package SimAdvLIGO by Matt Evans
  - » Digital LSC, no ASC, quad pendulum on initial LIGO SEI
  - » Locking code developed and studied for 40m prototype ifo
- Electronics Architecture
  - » Identification of shortfalls in Initial LIGO design and execution – lots of lessons learned
  - » Proposals for changes in computing infrastructure, approach to ADC/DACs, power, packaging…
  - » Attention to problem of lack of readback
- Timing system: Szabi Marka at Columbia to take this on
  - » Working on requirements and conceptual design

Suspensions



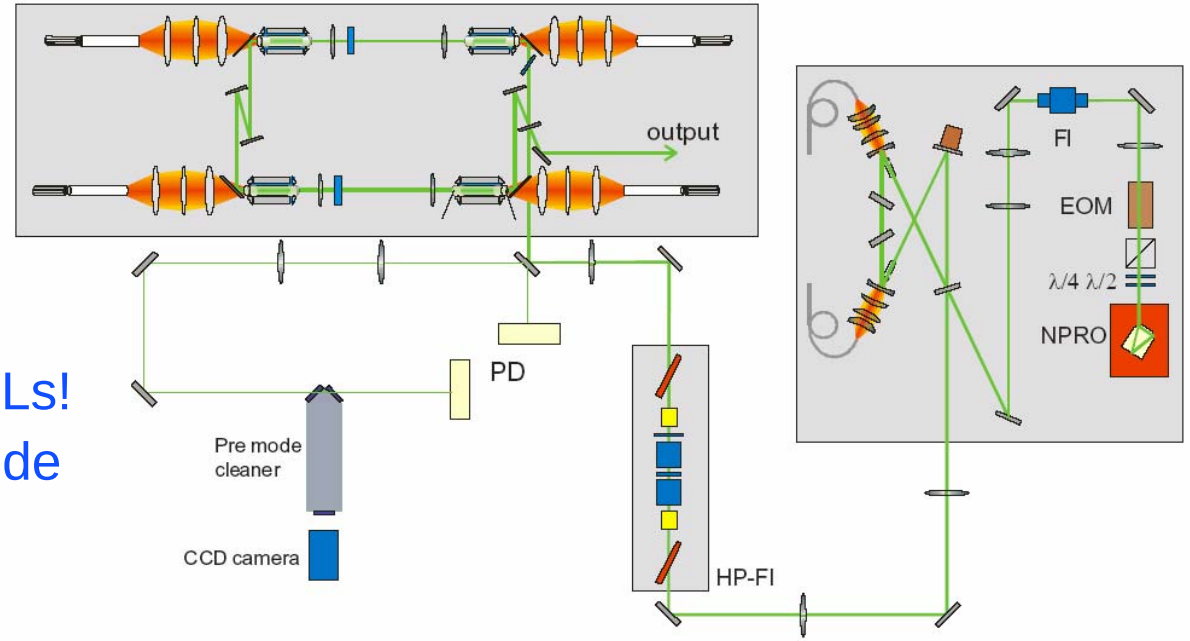
- Test Mass ‘Controls’ Quad Suspension built
  - » Mass catcher or ‘cage’ from UK
  - » Spring design, mass design from Caltech
  - » Initial testing, then cleaning → LASTI at MIT
- ‘Ear’ design, fabrication, bonding
- Electronics review to give UK team go-ahead



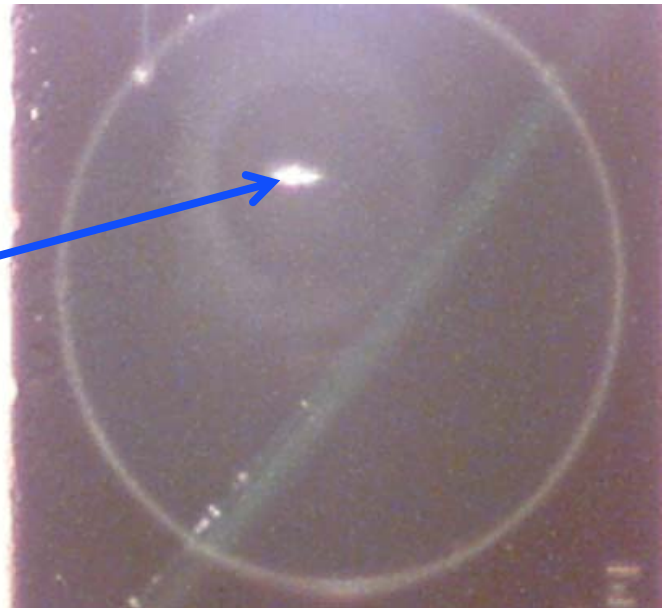
- Tests of UK Osem design/dSpace controls
- Installation fixture design in second phase
- Variable feed/pull fiber fabrication machine
  - » Uses CO2 heating of fused silica material
  - » Allows control of neck shape
  - » Can make round or rectangular ribbons
- Currently in assembly, testing soon

Pre-stabilized Laser

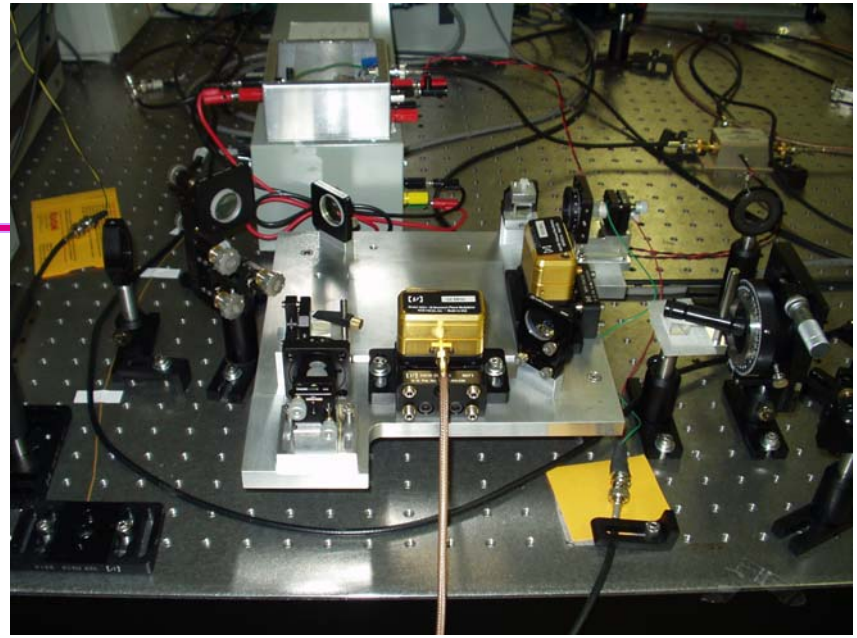
- Development at Max-Planck Hannover, Laser Zentrum Hannover
- Max Planck has granted funds for delivery of all PSLs!
- Continued work on the mode shape of 200W laser



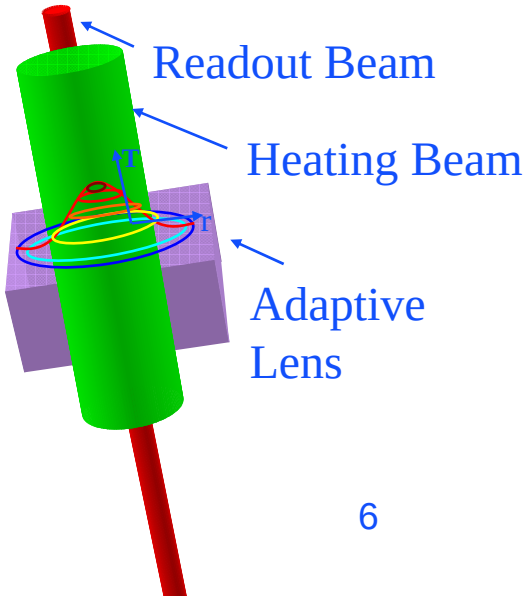
- Work on photodiodes for intensity stabilization at Caltech
  - » Purchasing Innolight laser (as for LZH system)
  - » Stress-testing detectors
  - » 600 mA, one minute…..



Input Optics

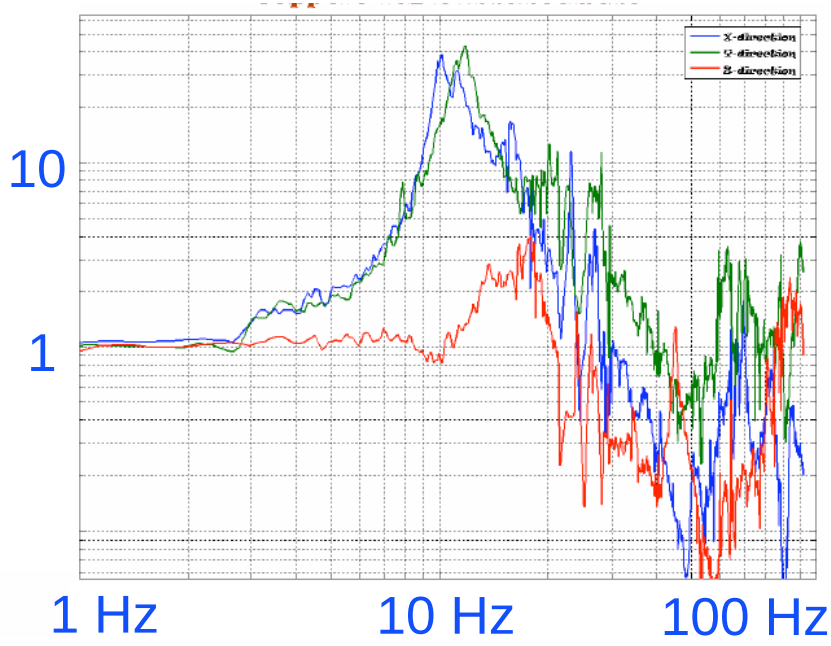


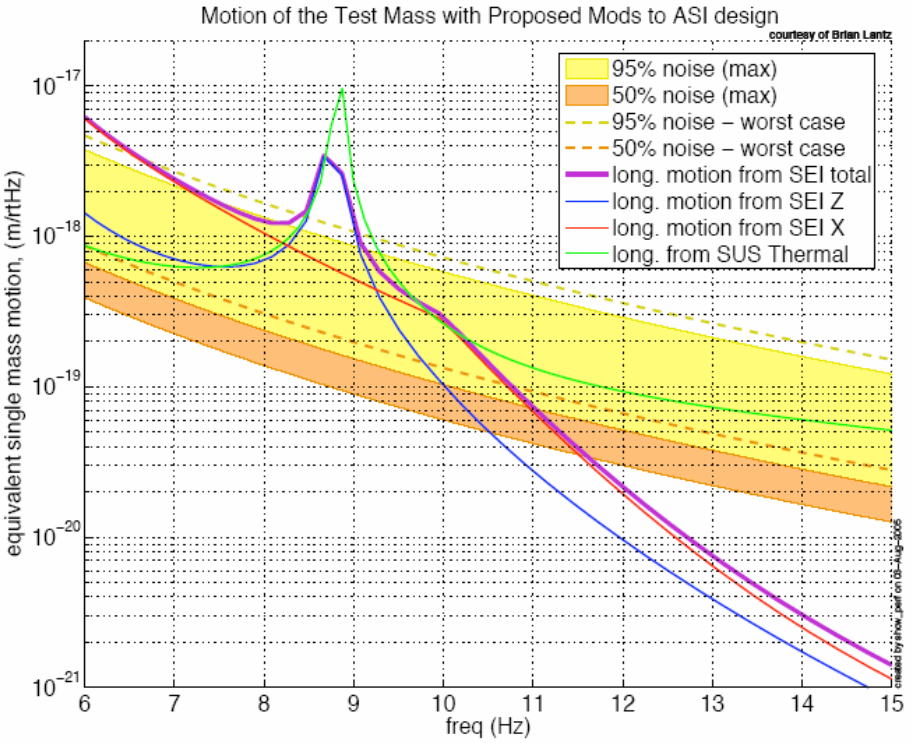
- Subsystem at U Florida
- Mach-Zehnder modulation system
  - » Theoretical investigations of noise couplings
  - » Prototype MZ EOM developed
    - – Locked; undergoing characterization
- EOM noise measurements
  - » Excess phase and amplitude noise
    - – Modulated, intensity-stabilized NPRO beats against 2nd-locked, intensity-stabilized NPRO
- Adaptive MMT Development
  - » Completed focal length and cavity mode analysis of table-top experiments
  - » Excellent agreement between theory and experiment
  - » No measurable higher order mode contamination
  - » Two element telescope using CO_2 heating laser and fused silica mirrors Experiments underway at UF



Seismic Isolation

- High-gain servo controlled platform
- Test Mass SEI (BSC) Critical Review complete, report in editing
- Significant progress in understanding and performance of Stanford prototype
- Design tuning to meet requirements
  - » lower natural resonant frequencies, detailed design pursued by ASI Inc.
  - » customization of seismometer readout to reduce electronics noise
- Amplification of motion at top of piers is real, and (relatively) independent of load – increases seismic input at 10 Hz
  (figure from LASTI@MIT)
- Moves point of crossing 10^-19 m/rHz from 10.0 to 10.6 Hz
- Coupled SEI-SUS dynamics analysis furthered -- appears to be manageable
- Proceeding with plan to build, should be ready to install in ~1 year





Seismic Isolation

- HAM Isolation Design next focus
- Reviewing the requirements – may be possible to relax them, may or may not be advisable in the big scheme
- Stanford-ETF-like system is the baseline
  - » Could pursue the current realization (‘HPD’) or a design more similar to the BSC (‘ASI’)
  - » Studies of the performance of a single-stage system (would deliver ‘relaxed’ requirements at lower cost, complexity)
  - » Looking at ways to profit from experience with lower natural frequency approach, design concepts or elements – want to make sure we get the most out of the pool of available knowledge and manpower

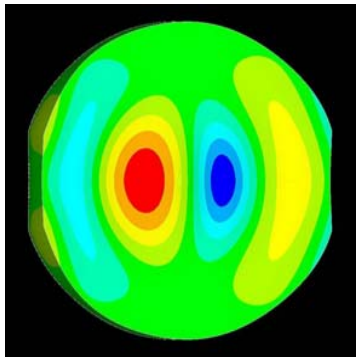
Core Optics

- Pursuing the chosen fused-silica substrate material.
- Substrate for LASTI ‘noise prototype’ quad suspension acquired
  - » A first pass through handling (40 kg….) and processing
- In discussion with Heraeus, a very likely supplier of the fused silica substrates
  - » technical points – annealing, dn/dt, potential alternative materials
  - » for acquisition of UK-supplied substrates – near-term
  - » The UK is in the process of ordering 4 ITM blanks, Heraeus 311
- Received a first response from our LIGO 1 polisher on Advanced LIGO specs
  - » “It looks a bit dicey” (G. Billingsley, 2005)
  - » going over the specification in detail with an eye to asking for exactly what we need in the areas of concern.
  - » Re-building the FFT code for the long-term, modal analysis near-term
- Warming up effort to look at Charging issues via Kelvin probe measurements
- Thermal compensation: using video projector DLP chip as CO_2 beam former!

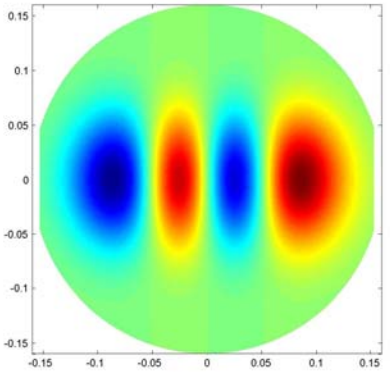
Core Optics

- Parametric instability – excitation of internal test-mass mechanical resonances by higher-order optical modes of arm cavity which are excited by internal test-mass mode…
  - » Recognized by MSU group; further explored by UWA group
  - » Working on getting reliable numerical estimates for AdL situation, considering various means of controlling
- New results from ACIGA-LIGO collaboration
  - » Realistic mechanical Q-factors
  - » FFT-modelled high order modes
- Typically 10 unstable modes per test mass
- Strong sensitivity to test mass radius of curvature
- Passive and active control methods proposed
- Will test at Gingin

Mechanical mode
47.27 kHz

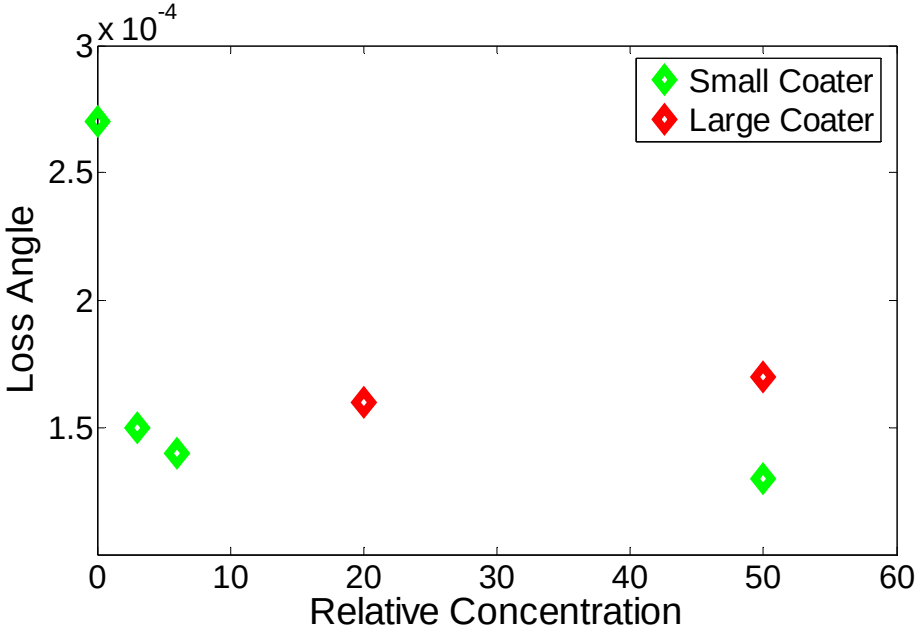


Optical mode



Overlap: 0.800

Optical Coatings



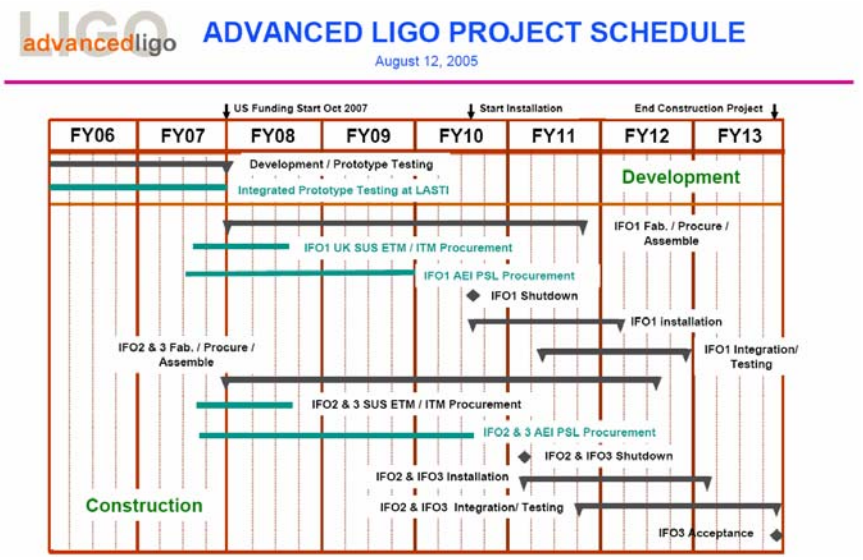
- Goal: ~10x reduction
  from 5 10^{-4} to 5 10^{-5} loss angle
  - » Brings coating noise down below substrate Brownian noise
  - » Halfway there (1.5 10^{-4})
- Increasing Titania dopant reduces mechanical loss (LMA)
  - » Appears that a bit of dopant 'saturates' the effect
- Losses effectively independent of polish (cuts cycle costs and time)
- Studies of absorption and scatter in parallel to ensure all requirements can be simultaneously met – best values seen 0.4 ppm loss, 20 ppm scatter
  - » TBD if this can be maintained for coatings on a full-scale substrate, through installation
  - » Understanding of the problematic LHO optics very important for AdL!
- Discussion of optimization via variation of layer thickness
- Coating of new mirrors for a TNI direct measurement of the state-of-the-art coatings

Experiments and prototypes

- 40m: Inching toward a lock of all DOF with no offsets; already see intriguing behavior in detuned RSE. DC readout reviewed.
- LASTI: Research into pier (?) amplification at 10 Hz, Alternative HEPI control law development, understanding of structural resonances of BSC
- TNI: Preparing for test of next generation coatings
- MexHat: Working with the cavity; comparing modes observed with those calculated
- Gingin: Thermal lens compensation and Hartmann off axis wavefront sensor working. Preparing to test parametric instability. Advanced isolators and suspensions near completion in second arm
- ETF: Getting great performance out of the Seismic Demonstrator; moving toward a combined SEI-SUS structural test

Adv LIGO Implementation

- Review of project-phase costs, manpower, schedule complete
  - » Fresh analysis by fresh eyes, updates of technology; about as many forgotten as duplicated items found
  - » With current best estimate, costs compatible with those approved by the NSB
- President's budget calls for Oct 2007 funding
  - » Contingent on indication that we are achieving Initial LIGO goals!
  - » Start fabricating long-lead items, build up stock of isolation systems, etc.
  - » We remain poised to take advantage of any earlier funding that might be available…
- Baseline plan calls for shutting down the first Initial LIGO ifo in mid-2010, accepting the 3rd AdL ifo in end-2013



Advanced LIGO R&D

- Good progress on designs and prototype tests
- Working to fit a robust R&D Lab program in the available funds, available manpower
- Anticipating an NSF review, in early Spring 2006, of Advanced LIGO as a Project
- Believe Advanced LIGO has a good chance for October 2007 funding