Advanced LIGO Update

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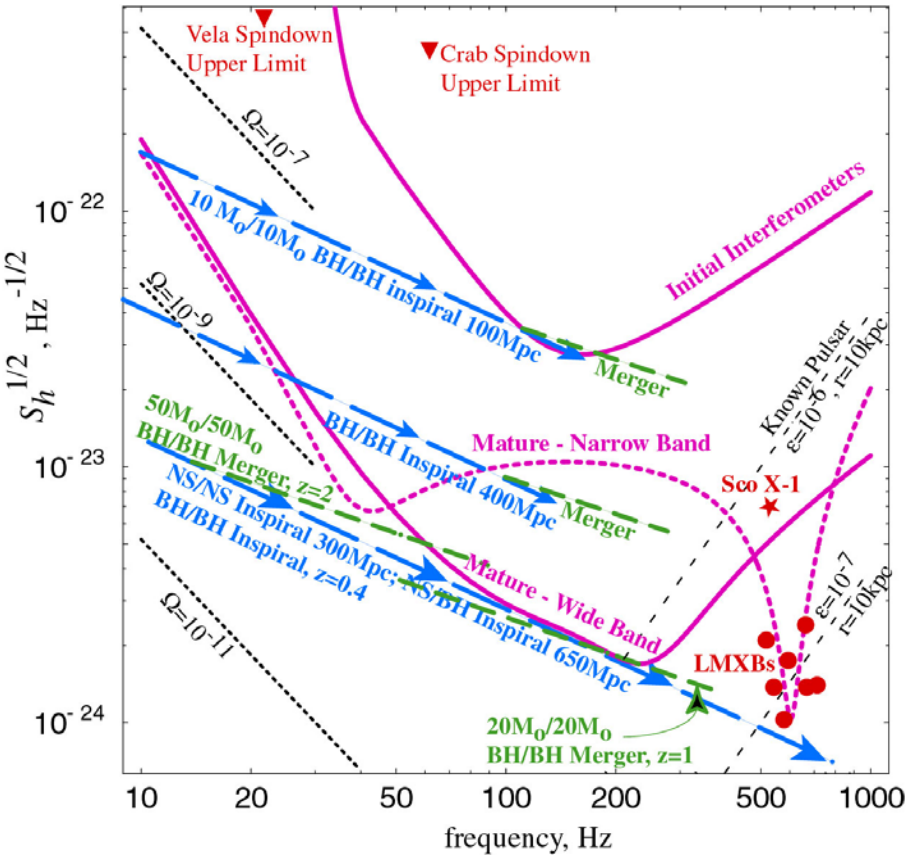
LSC LLO March 2005

Advanced LIGO

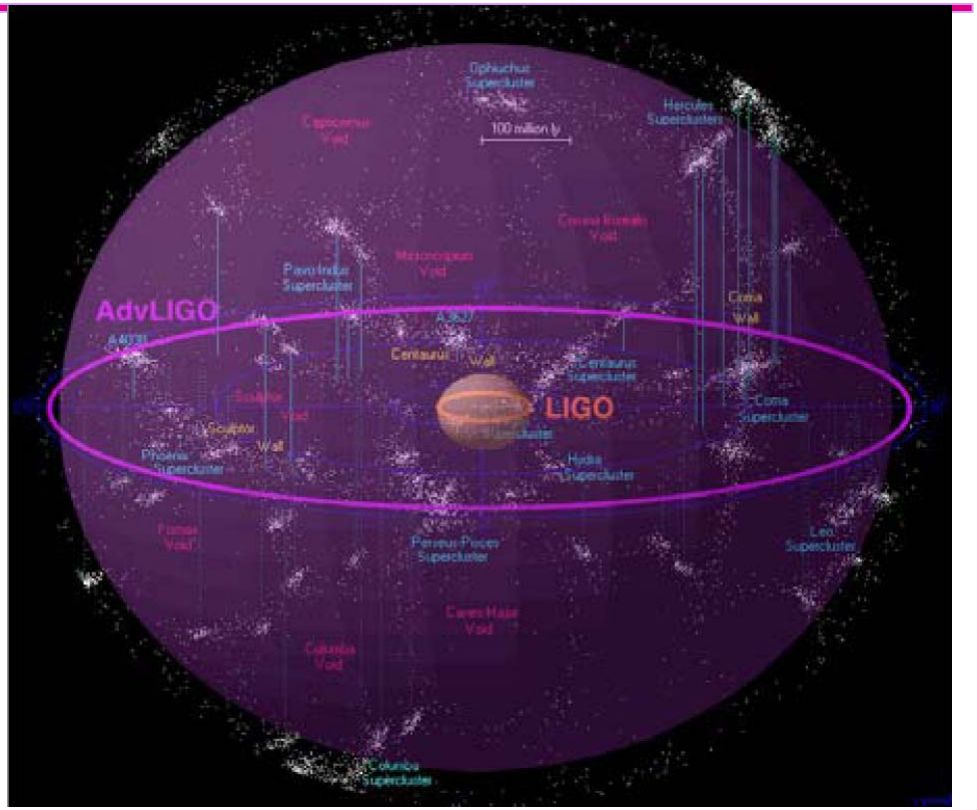
- A reminder ...
  - » ~Factor 10 in amplitude sensitivity
  - » ~Factor 4 lower frequency
  - » Tunable
- Recombined Fabry-Perot Michelson
  - » Signal recycling
  - » ~20x higher input power
  - » 40 kg masses
  - » Fused silica suspension
  - » Active seismic isolation, quad pendulum suspension



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

Construction Project Status

- NSB endorsed the Advanced LIGO construction proposal (Oct '04)
  - » Contingent upon an integrated year of observation with Initial LIGO
- NSF & Presidential Out-year Budget includes LIGO!
  - » LIGO is one of 3 proposed new start projects in the next 3 years
  - » NSF has proposed an FY08 funding start (FY07 start is a possibility)
- AEI
  - » Presidential Board of the Max Planck Society has endorsed AEI plans for Adv. LIGO material contribution
- Lab Planning:
  - » Research, Design & Development (RD&D) phase aimed toward FY07 MREFC start
  - » Continuing to refine plans, costs and contingencies
  - » Anticipate a detailed baseline review for MREFC ~mid 2006



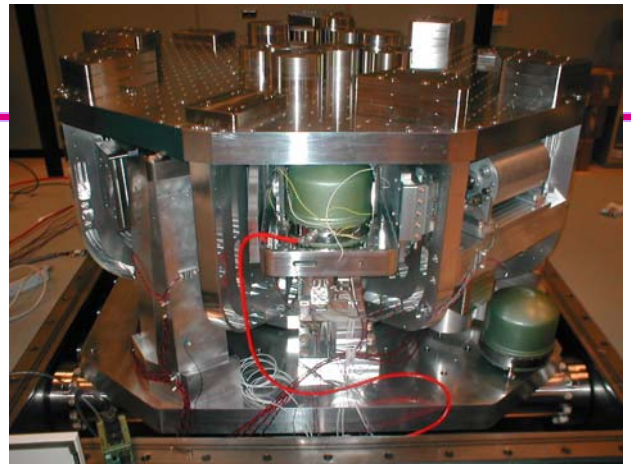
Sky map showing locations of superclusters, walls, and voids of galaxies within about 500 million light years. Superimposed circles show the range of LIGO (orange inner circle) and the 10 times larger range of AdvLIGO (purple outer circle). The milky way is at the center in this representation. *Credit: the underlying black and white image with names of clusters and voids is by Richard Powell; the superimposed color circles were added by Beverly Berger, Division of Physics, NSF.*

“Systems”

- R&D Test Facilities progressing well:
  - » 40m Lab
  - » LASTI
  - » Gingin
- Systems Engineering
  - » Refining the optical layout, Starting an integrated 3D optomechanical layout
  - » E2E Adv. LIGO modeling
  - » Systems trades, Requirements/Interface definition, …
- Project Management
  - » Refining the planning & costing for the baseline MREFC review

SEI

- BSC Design
  - » Our design contractor (ASI) has completed and delivered the detailed BSC design
  - » Critical Review: Are we still on track?
    - – Cost and programmatic review successful (Jan)
    - – Technical Review, informed by Stanford ETF testing, planned for ~May
  - » LIGO Lab will competitively compete the piece part fabrication
    - – After a go-ahead from the critical review, and any minor design modifications
    - – Procurement strategy being developed
- HAM design
  - » ASI has delivered a preliminary (layout) design
  - » After BSC fabrication is underway, LIGO Lab will complete the final design effort (likely as a subcontracted design effort)



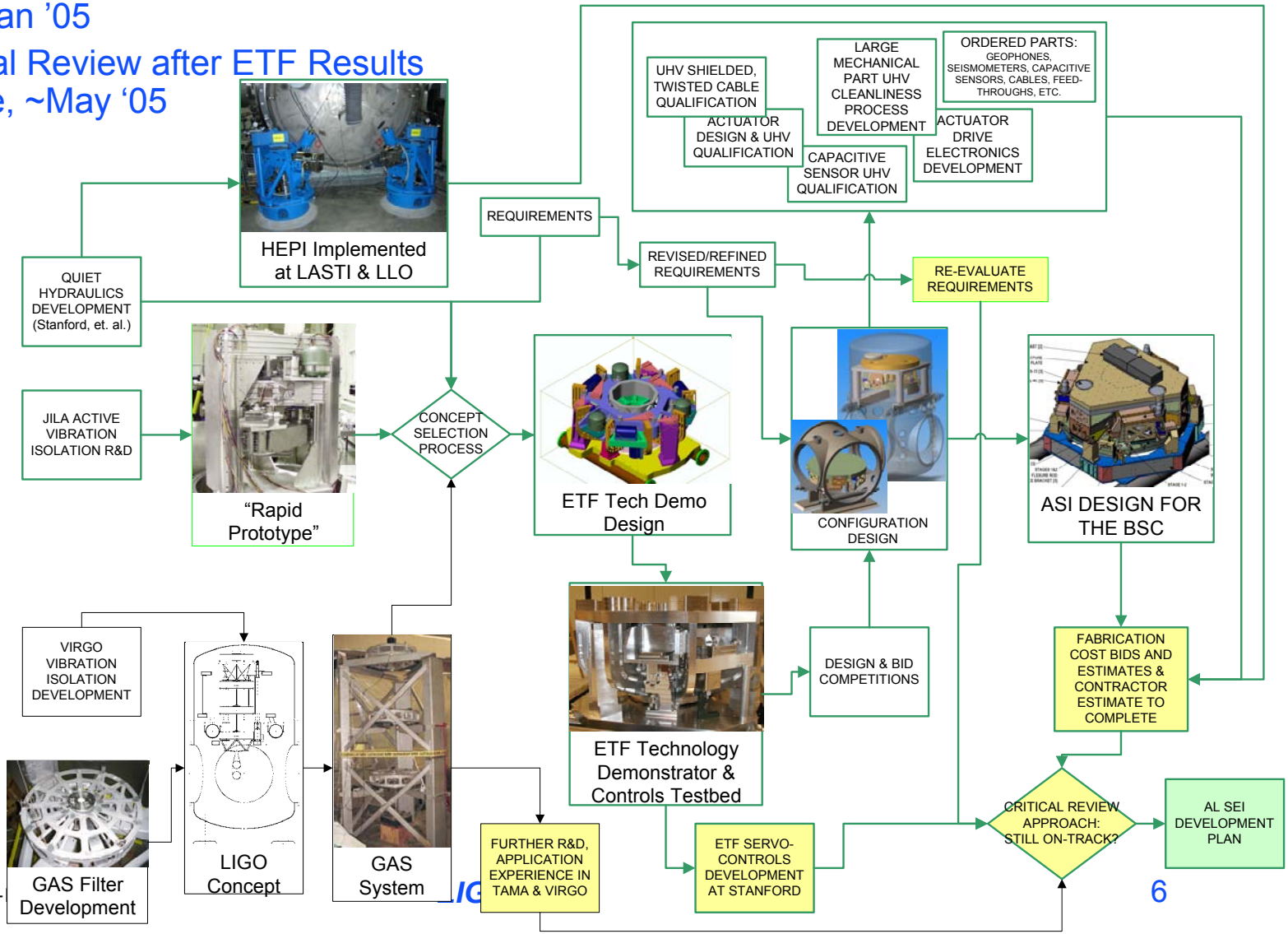
SEI Technology Demonstrator at the Stanford Engineering Test Facility (ETF)

Good Performance
(all 12 damping & isolation loops engaged)

- Plan suspension structure testing on the ETF active SEI system to investigate coupled dynamics

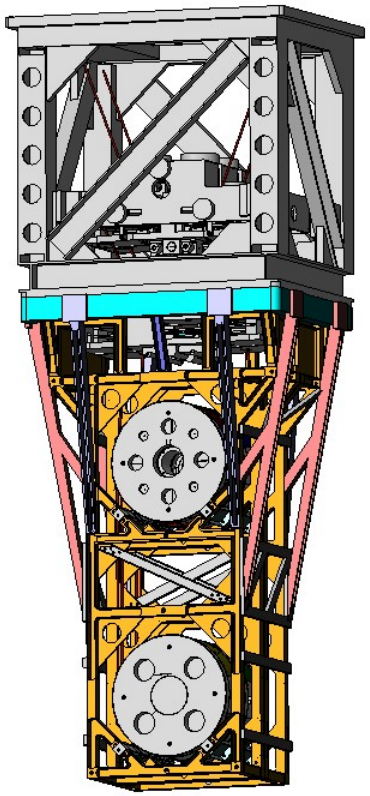
LIGO Seismic Isolation (SEI) Development

- SEI Critical Review
  - » Successful Cost & Programmatic review Jan '05
  - » Technical Review after ETF Results available, ~May '05



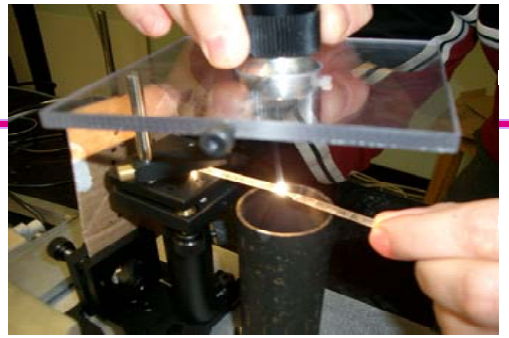
Suspensions

- Test Mass (Quad) Suspension
  - » Revised Cavity Optics Design Requirements Document released (T010007-02)
  - » 'Controls' Prototype
    - – 'Dirty' sub-assembly underway
    - – Design & Fabrication complete ~May
    - – Delivery to LASTI planned early summer
  - » 'Noise' Prototype
    - – Concurrent Design by the UK Team (under PPARC funding)



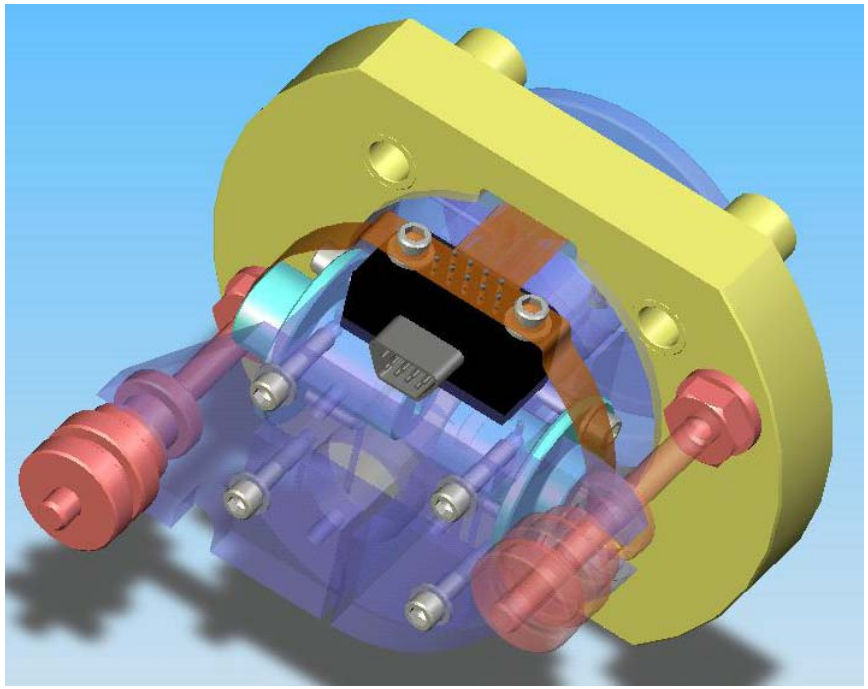
- Mode Cleaner (Triple) Suspension
  - »LASTI Testing of controls prototype completed
  - »Performance as expected
  - »Model-measurement comparison caught some model shortcomings & an as-built difference

Suspensions



Welding 3mm silica rod with 9W CO_2 laser

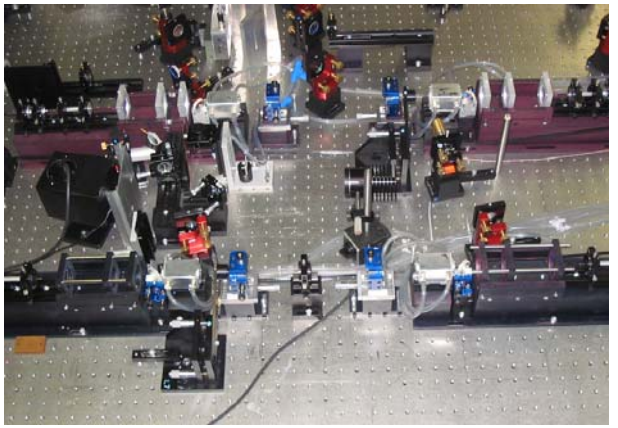
- Silica Fiber/Ribbon Pulling
  - » R&D on computer controlled CO_2 laser system proceeding well
  - » Fibers up to 570 mm long, 184 $\pm$ 5 microns diameter (15 microns dia. repeatability) with 3 GPa breaking stress (factor of safety $\approx$ 4)
  - » Ribbons produced with the beam oscillating across the stock by mirror galvanometers (4 mm x 150 microns typ.)
- Fiber/Ribbon Welding
  - » Fiber & ribbon welding demonstrated
  - » Working to improve welded strength
- Eddy Current Damping
  - » Component design is complete
  - » Optimizatizing location for selected DOFs
- Electrostatics
  - » Mask fabricated on penultimate mass
- Electronics
  - » Optical Sensing & Electro-Magnetic actuator (OSEM) assembly Preliminary design:
    - – Mechanical design complete
    - – Electronics well underway
  - » Damping Controls test stand fabrication & assembly completed at Caltech (dSpace version)

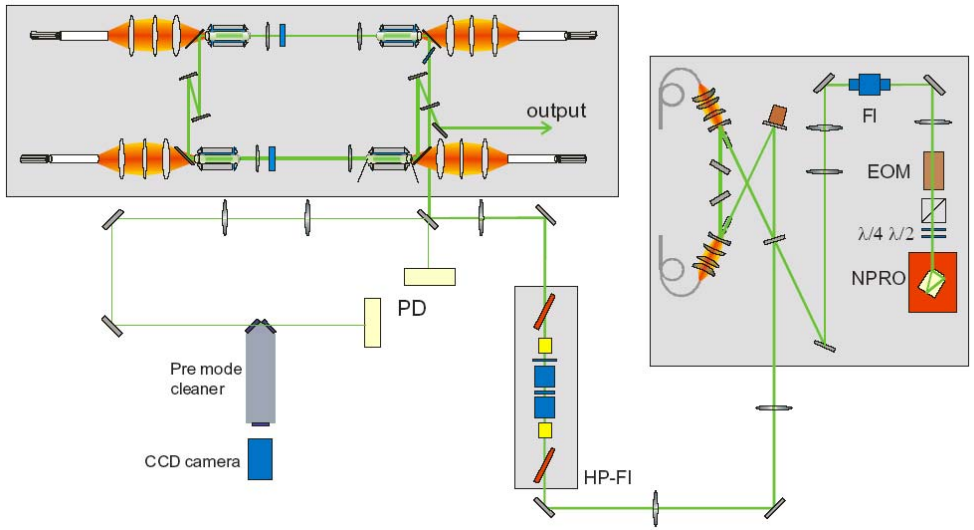


Modified Hybrid OSEM Design

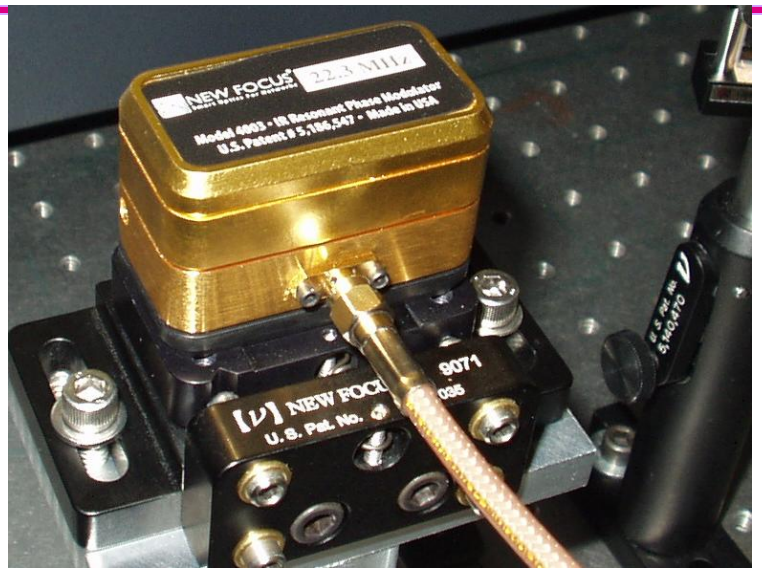
Pre-stabilized Laser

- Injection locking of the 200 W Laser (LZH, AEI)
  - » Automatic: Re-locks 3 stage system in less than 1 sec
  - » Reliable: Durations > 40 min
- Characterizing spatial and temporal behavior
  - » Higher order mode content measured with LIGO-like Pre-Mode Cleaner (PMC)
  - » Spatial profile has donut mode after upgrade of components (100 W to 200 W)
    - – Laser crystal Erbium doping too high
    - – Thermal compensation lenses out of specification (fixed)
- Relative Intensity Noise (RIN) Stabilization
  - » Outer loop power stabilization implemented on GEO600
  - » Mode Cleaner introduces RIN on the beam – effect being studied





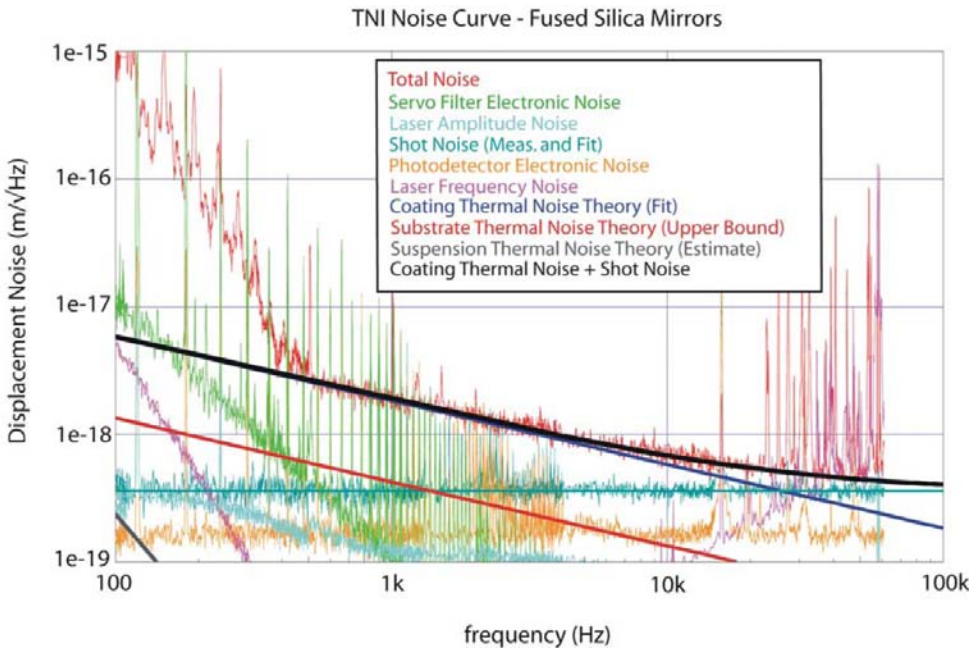
Input Optics (IO)



- LLO High Power Laser Facility (HPLF)
  - » Operational (clean room, safety prototcols)
  - » 100 W CW 1064 nm linearly polarized Yb fiber laser is in spec
  - » Reliability problems; since delivery failed 4 times
- Faraday Isolator
  - » 20 mm aperture with thermal lensing & depolarization compensation
  - » 20% thermal lensing of an uncompensated isolator
  - » Total depolarization of -35 dB at 180 W
- Modulation
  - » Received two New Focus EOMs with low absorption RTP crystals
  - » No damage at 85 W for > 400 hrs at irradiances greater than for AL
  - » Mach-Zehnder interferometer being assembled with monolithic mechanical ‘backbone’
- IO Design
  - » Building layout & Components in 3D SolidWorks
  - » Will use Fused Silica for the Adaptive Mode Matching Telescope; Measured Thermal Distortion with Schott OG-515 is too high
  - » Melody Model of the Mode Cleaner indicates that an Absorption Coefficient of 1 ppm can be tolerated

Coatings

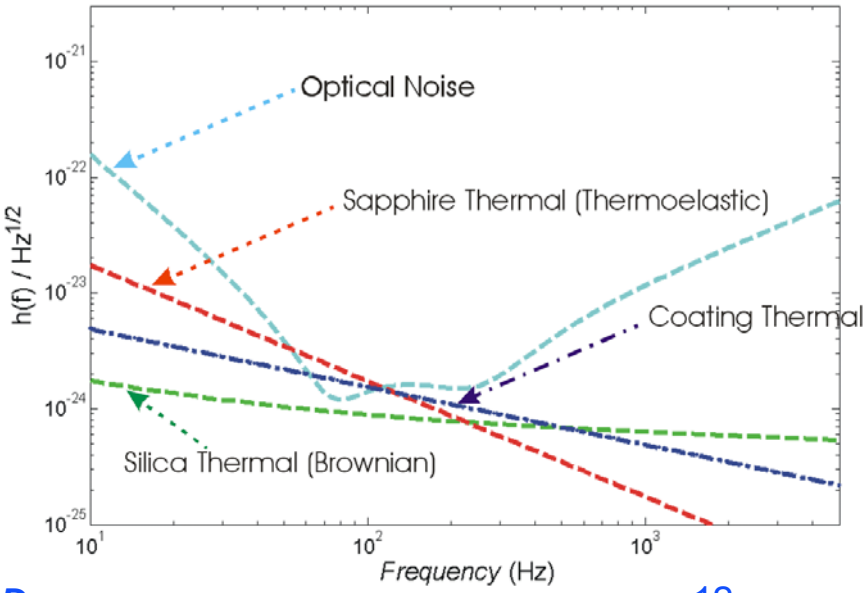
- Mechanical Loss Goal: ~10x reduction from 5 10^{-4} to 5 10^{-5} loss angle
  - » Brings coating noise down below substrate Brownian noise
  - » Increases NS-NS 1.4 Ms from ~160 Mpc to ~200 Mpc
- Need to reduce coating thermal absorption inhomogeneity
- Sense is that we can get pretty close with incremental improvements
  - » New results on Tantala doping and single layer materials
  - » New design algorithm for non-periodic, multi-layer dielectric coating decreases thickness of high mechanical loss Tantala



Core Optics

	Sapphire	Silica
NS-NS 1.4 Ms	191 Mpc	191 Mpc
BH-BH 10 Ms	920 Mpc	1050 Mpc
Pulsar h/√Hz	7 x10^{-24}	12 x10^{-24}
Omega	4.8 x10^{-9}	2.6 x10^{-9}

- Substrate selection = Fused Silica!
  - » Recommendation based on a comparative study of FS & Sapphire
  - » either material could work, but more risks for sapphire
  - » FS better at low frequencies (high mass BH-BH)
  - » Sapphire better at high frequencies (LMXB)
  - » Coating loss dominates
    - – limits to ~160 Mpc (NS-NS 1.4 Ms)
- Lab work:
  - » Annealing?
  - » Scatter and absorption characterization of Initial LIGO optics for possible H1 ITM replacement pre-S5
  - » Developing & characterizing:
    - – optical loss for improved cleaning procedures
    - – Required particulate cleanliness levels



Advanced LIGO RD&D Summary

- RD&D phase plans are being adjusted to
  - » accommodate limitations in LIGO operations funding
  - » a stretched development phase
  - » delayed SEI development
- The SEI Critical Review process is proceeding well
- Fused Silica has been selected as the Test Mass material (over Sapphire)
- ¡The NSF, NSB and the OMB have endorsed the Advanced LIGO Construction project!
  - » MREFC funding start nominally FY08