Advanced LIGO

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Hannover LSC

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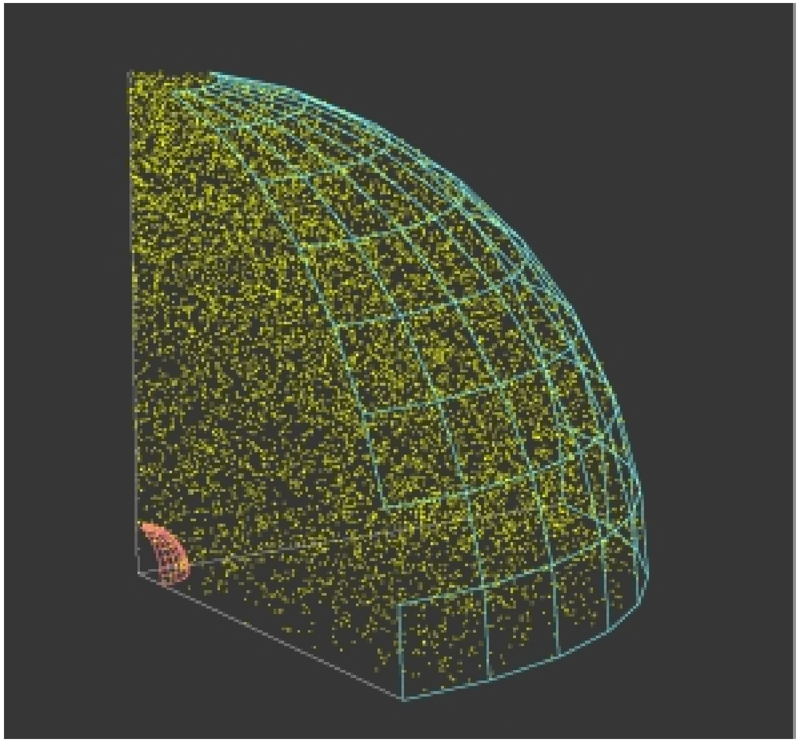
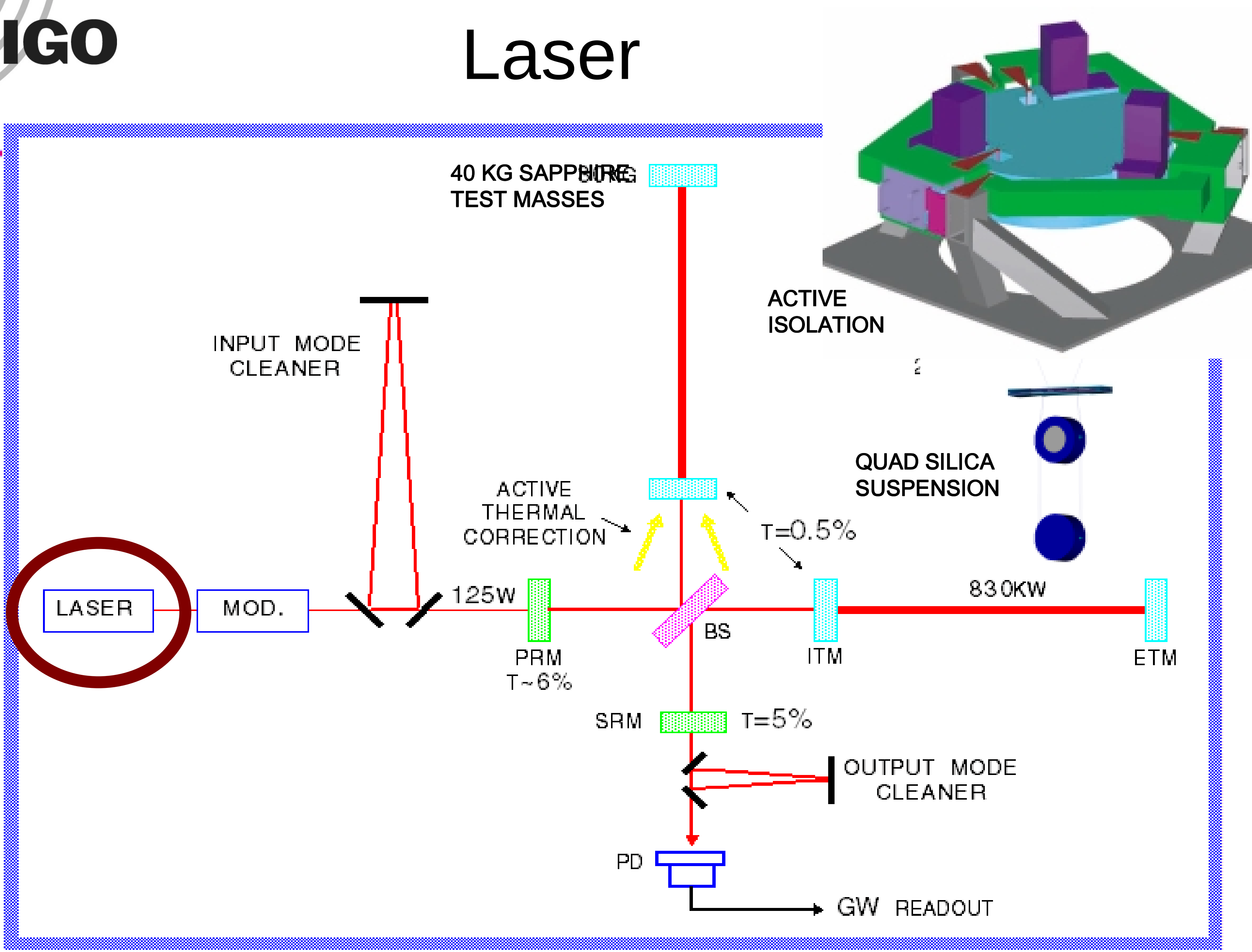
Advanced LIGO

- Advanced LIGO proposal submitted, February 2003
  - » 3 interferometers, each 4km
  - » Signal recycled configuration
  - » ~180 W laser
  - » Sapphire substrates
  - » Quad monolithic suspensions
  - » Active isolation system
- Working its way through the NSF
- What’s new technically?



Laser


40 KG SAPPHIRE
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ACTIVE
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INPUT MODE
CLEANER
QUAD SILICA
SUSPENSION
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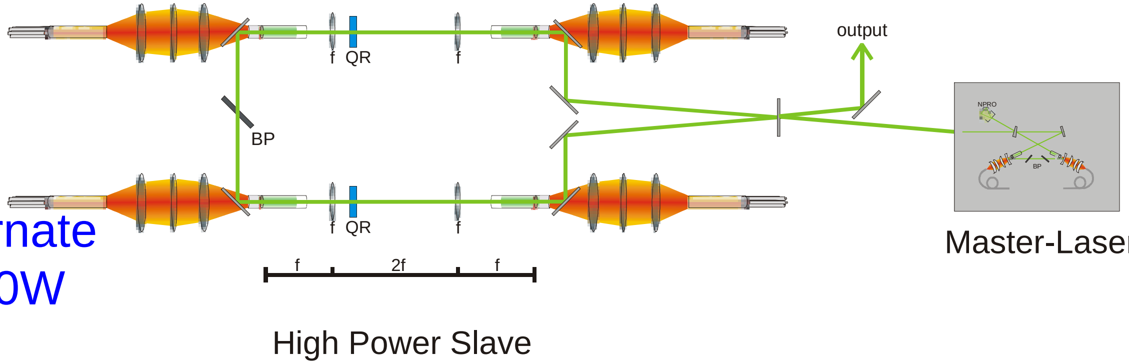
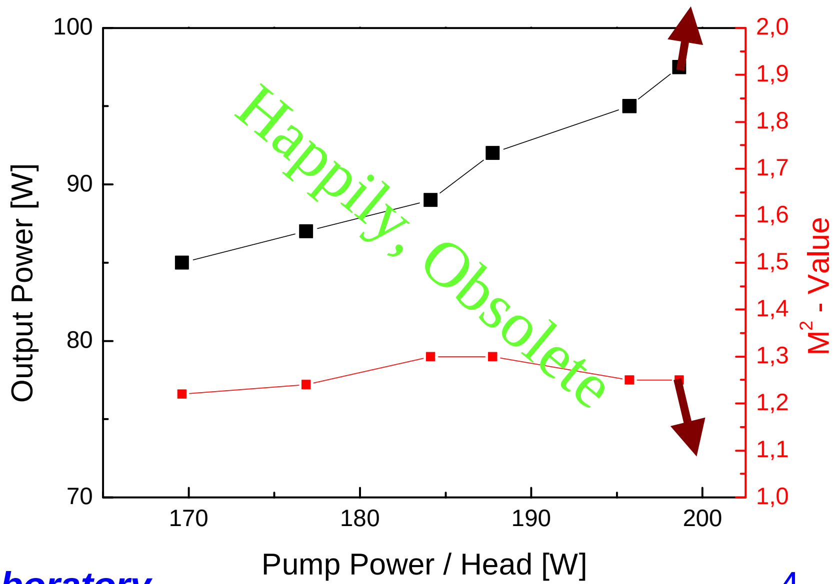
GW READOUT

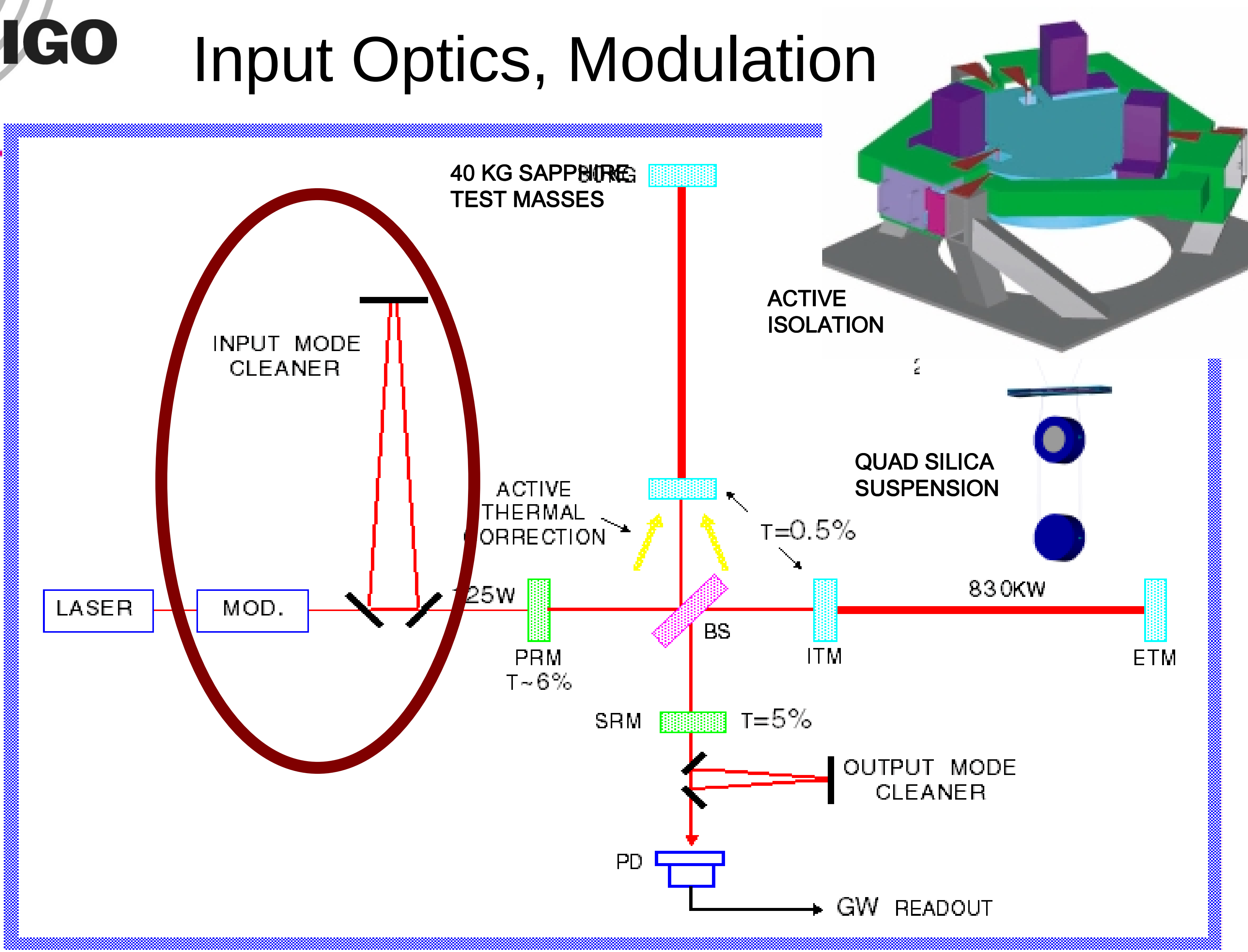
Pre-stabilized Laser

- Challenge is in the high-power 'head'
  - » Coordinated by Univ. of Hannover/LZH
  - » Three groups pursuing alternate design approaches to a 100W demonstration
    - – Master Oscillator Power Amplifier (MOPA) [Stanford]
    - – Stable-unstable slab oscillator [Adelaide]
    - – Rod systems [Hannover]
  - » LZH approach chosen as baseline March 2003
  - » With ½ of power head, P: 110 W, M^2x,y: 1.05





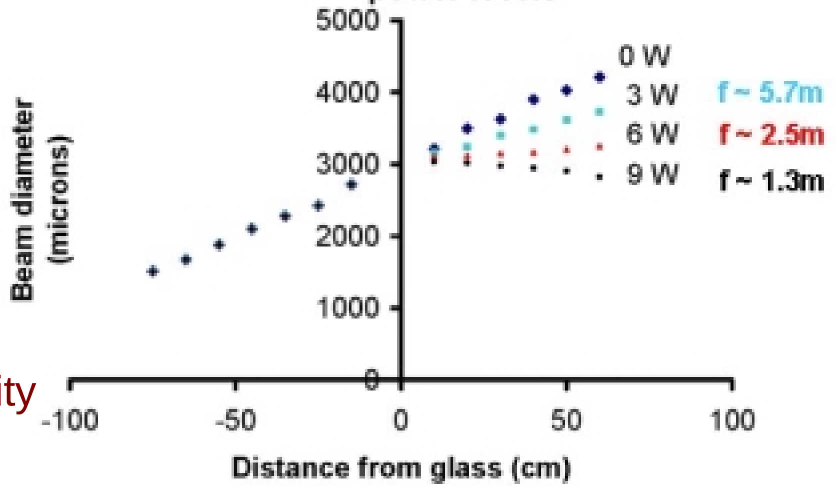
Input Optics, Modulation



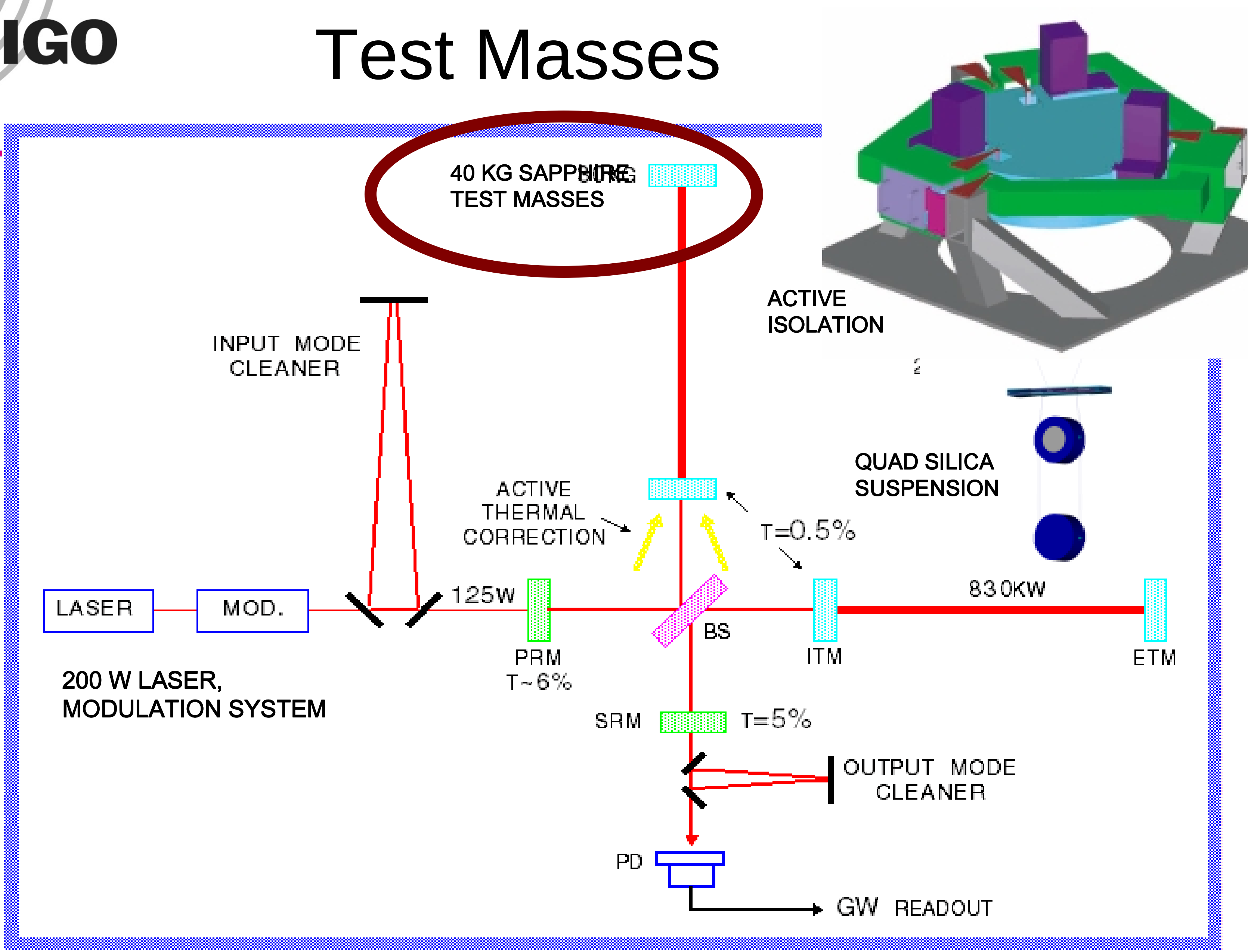
Input Optics

- University of Florida takes lead, preliminary design underway
- Complete RTP-based EOM prototype operational
  - » built-in temperature stabilization works
  - » undergoing high power modulation tests for RFAM stability
- Successful testing of fully integrated birefringence compensated, thermal lens compensated AdL Faraday isolator up to 40 W
  - » 40 dB isolation
  - » negligible thermal lensing, > 99% TEM00 in original basis
  - » moving to 20 mm clear aperture design
- LASTI/AdL MC optics spec'ed and designed
- Thermal modeling of AdL mode cleaner under way using FEMLAB and Melody
  - » no firm results yet, but discovered bug in Melody autolocker at high powers
- First demonstration of laser-induced thermal adaptive telescope
  - » large focal length dynamic range: 1 m < f < infinity
  - » modeling underway to analyze mode quality

FIG. 10a : Beam diameter (Y axis) vs. Distance from glass at various heating beam power levels



Test Masses



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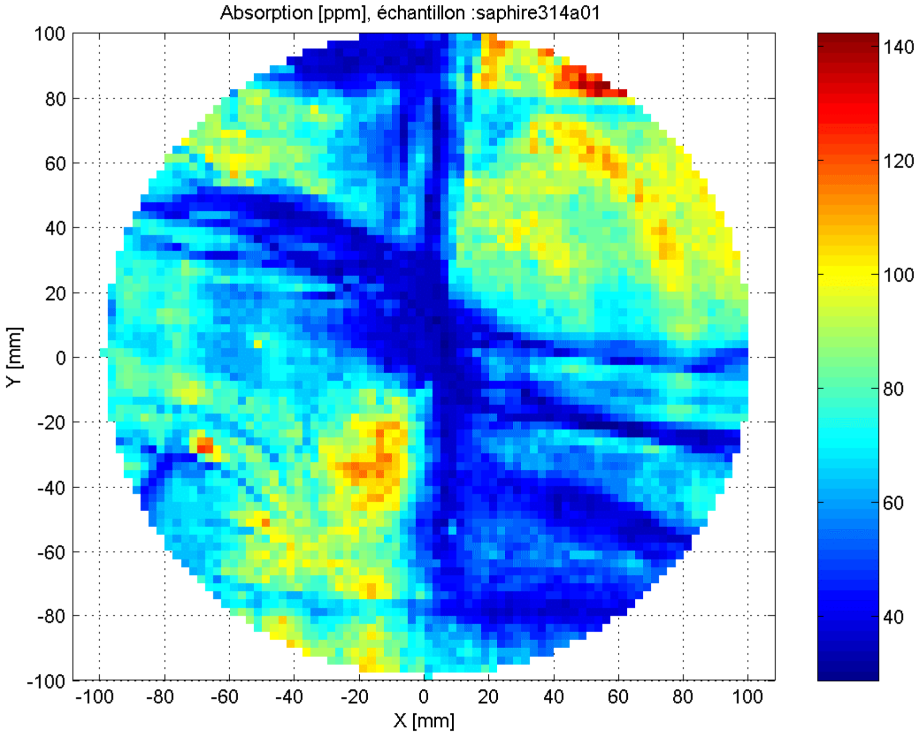
Core Optics: Sapphire

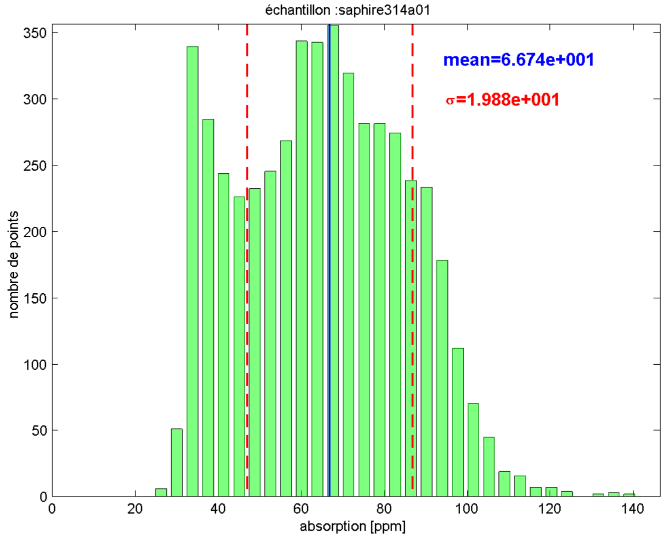
- Focus is on developing data needed for choice between Sapphire and Fused Silica as substrate materials
- Fabrication of Sapphire: 4 full-size Advanced LIGO boules grown, 31.4 x 13 cm; two acquired (one ‘nice’ and one ‘not so nice’)
- Significant characterization, generally very good results
- Remaining threshold: is absorption level, homogeneity workable or changeable?
- Downselect Sapphire/Silica (further) delayed to March 2004



Mean absorption: 67 ppm.cm^{-1}

ϕ 200 mm scan

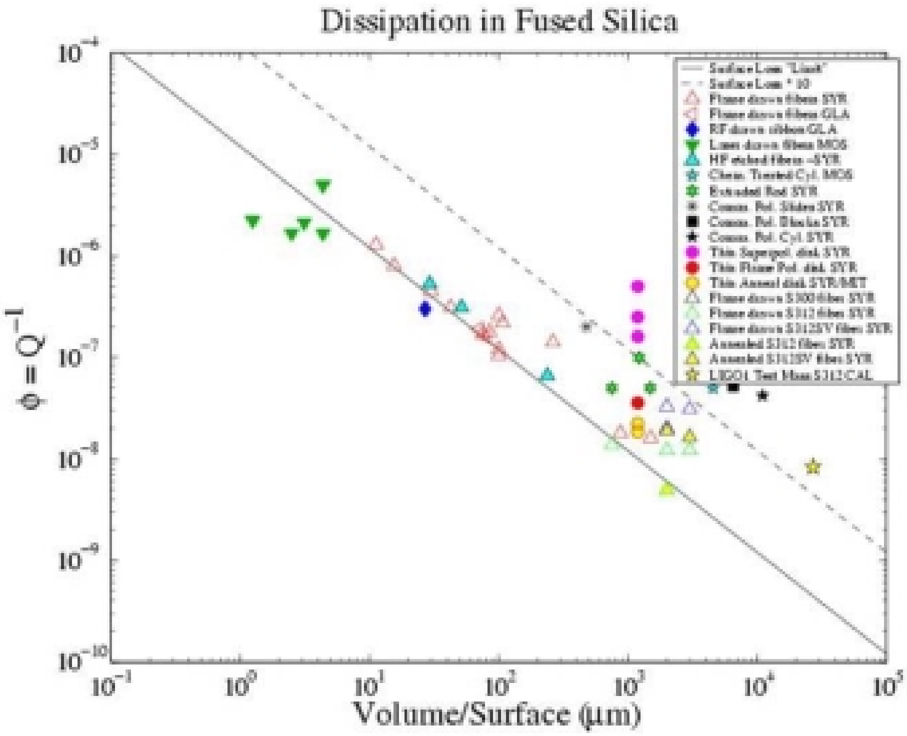
2.5 mm steps



Core Optics: Fused Silica

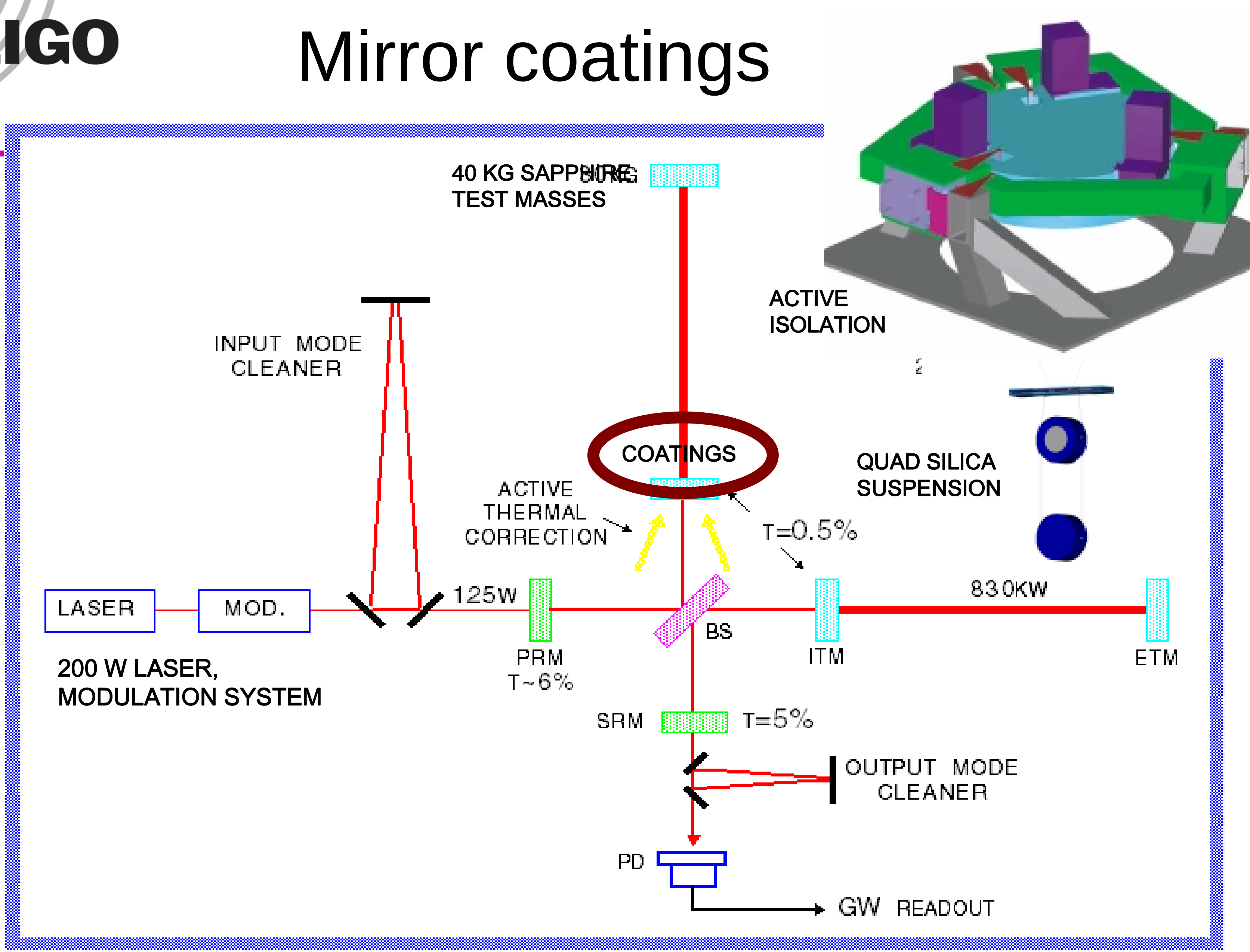
- (Good) Fall-back if sapphire unworkable – or ‘fall forward’ if it looks technically better

- New measurement: Heraeus 312
  - » 250mm x 100mm, CSIRO polish
  - » 120 Million Q
- Issue: optical absorption in Input Test Mass material
- Measurement of sizeable piece of SV underway
- Annealing furnace coming to HWS – 12”x12”x24”; will allow pursuing large-scale annealing



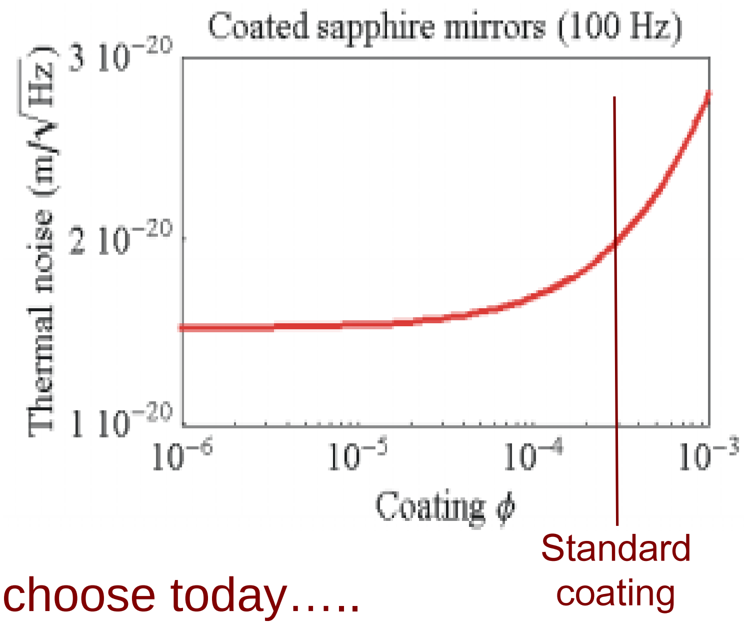
- Effort underway to refine annealing, realize procedure for polished optics

Mirror coatings



Coatings

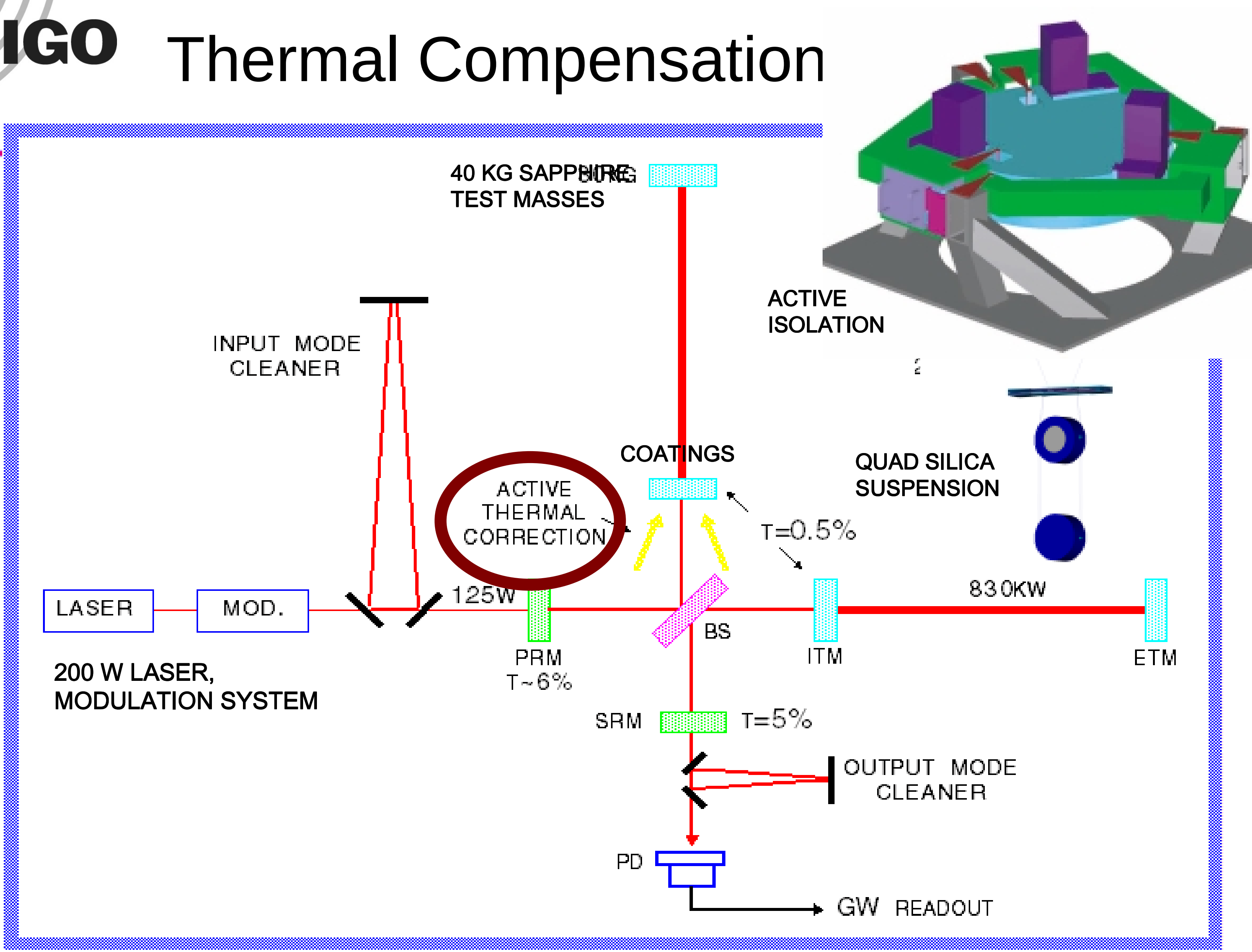
- Optical absorption (~0.5 ppm), scatter look acceptable for conventional coatings
- Thermal noise due to coating mechanical loss is the challenge
- Hiatus in coating experimental work while setting up vendor relationships
- Have just chosen CSIRO and SMA/VIRGO for next phase of coating experiments
- Thermoelastic noise pinned down (thermal expansion measured at MSU)



- Interaction with substrate properties, so if had to choose today…..
  - » Sapphire: Alumina Tantala (or Silica Tantala or Silica Alumina, similar)
  - » Fused silica: Silica Tantala
- Expanding the coating development program to other materials, processes
  - » Hafnia looks promising; talking more broadly with people in the field

- First to-be-installed coatings needed in ~2.5 years – sets the time scale

Thermal Compensation



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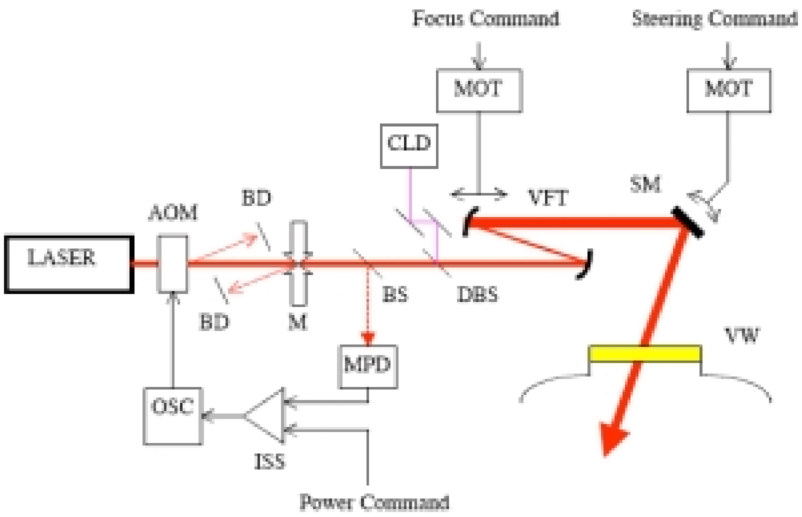
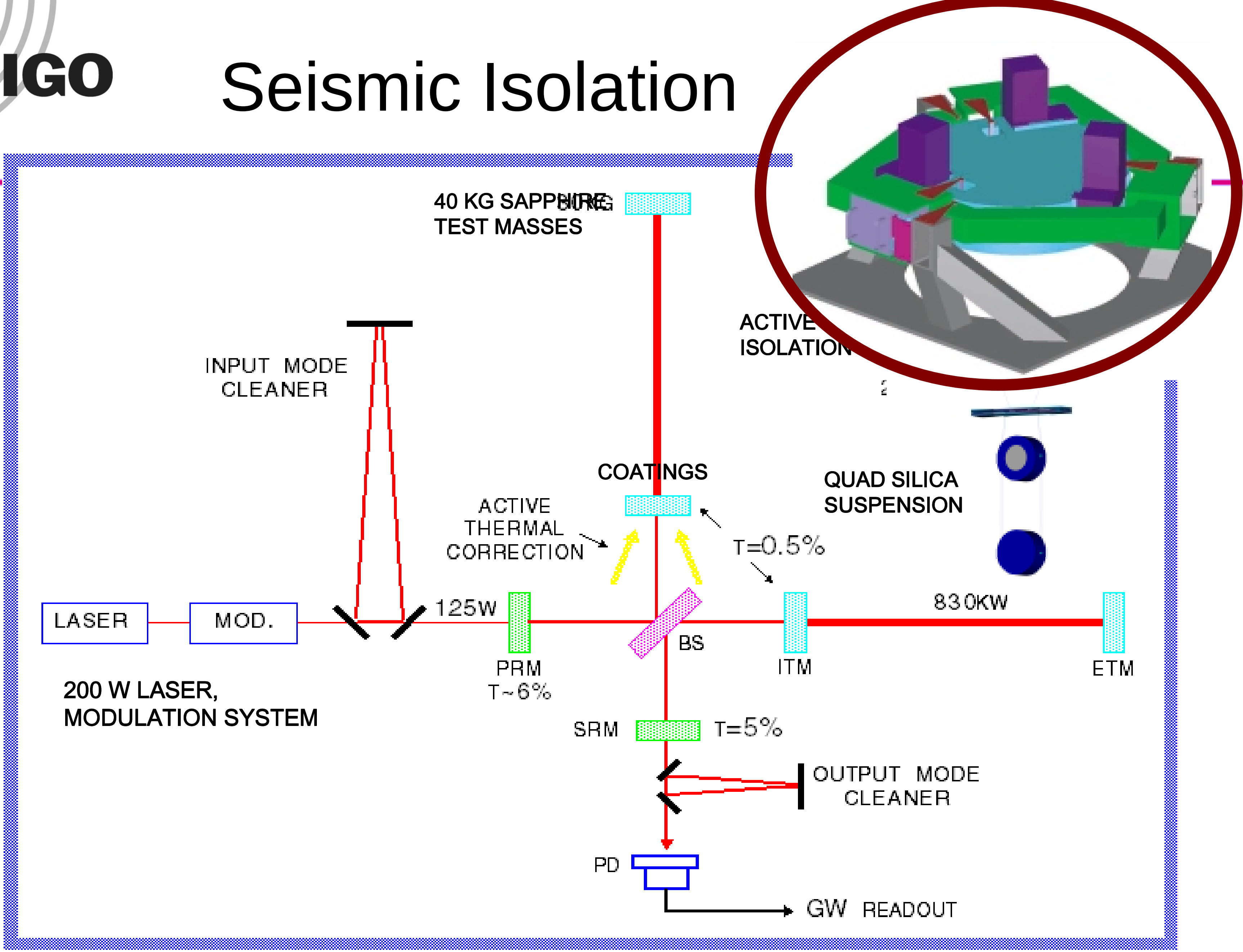
Active Thermal Compensation

- Removes excess 'focus' due to absorption in coating, substrate
- Plans, construction for tests at ACIGA Gingin moving along well
  - » Suspensions going together, substrates shipped
- May have a role in initial LIGO – optimization for available power
  - » Planning a 'staring' patterned CO_2 beam to heat (or 'cool') initial LIGO optics



Seismic Isolation

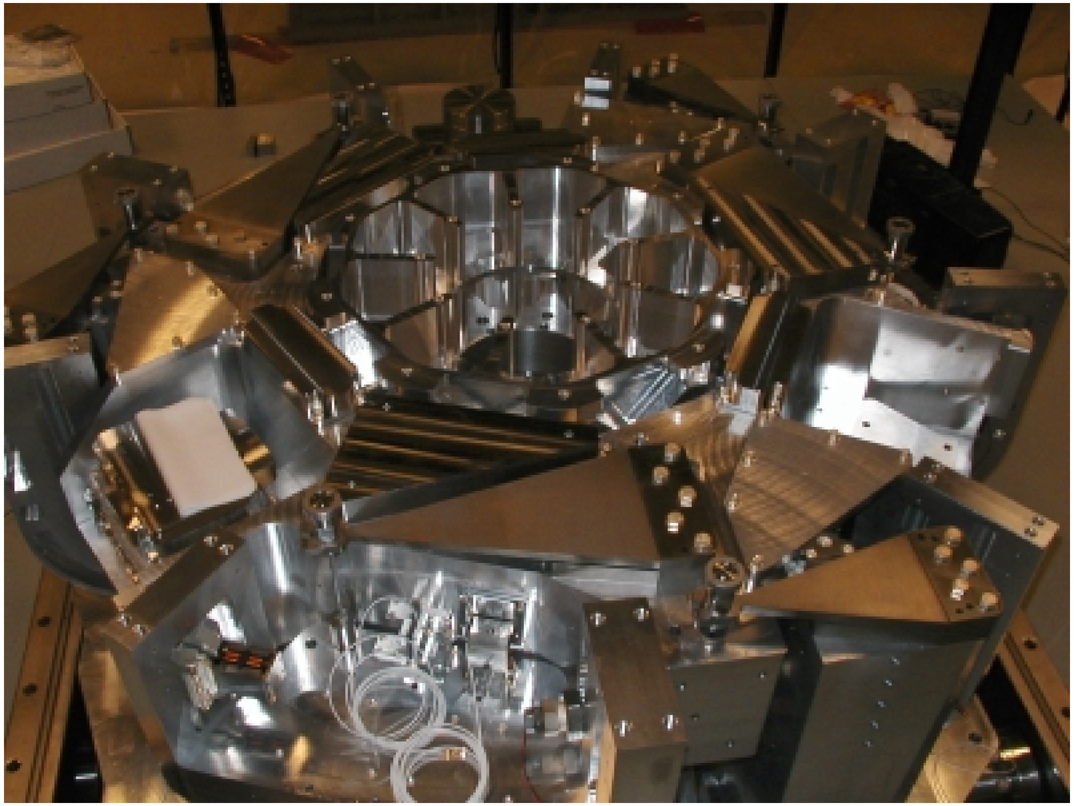


Isolation I: Pre-Isolator

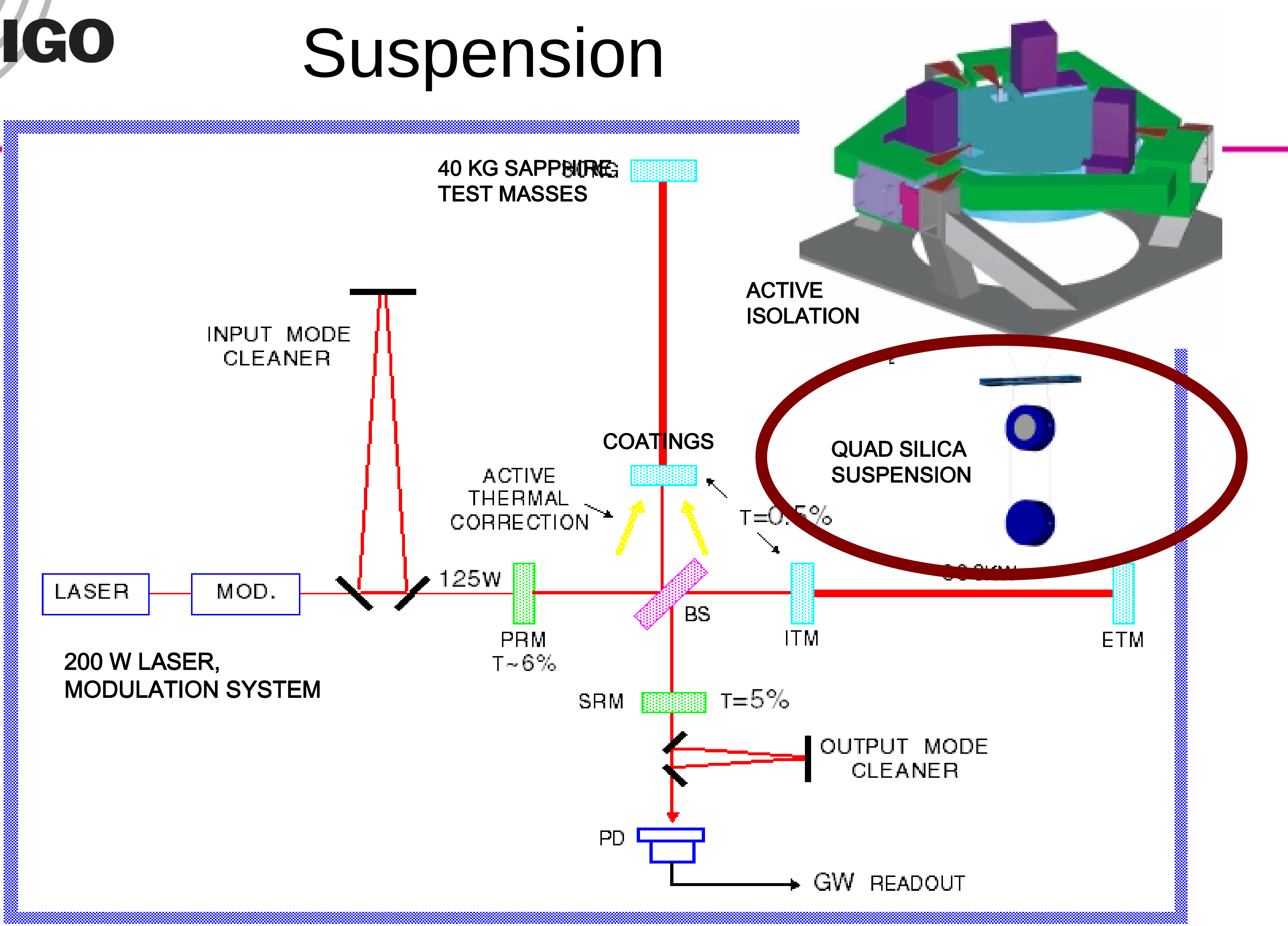
- Element of Adv LIGO – although LIGO I requires much higher performance than Adv LIGO
- Aggressive development of hardware, controls models
- Demonstration of requirements
- Approach chosen: Hydraulic External Pre-Isolator (HEPI)
- Tested on BSC; to be tested on HAM, at LASTI
- Parts in fabrication, planned installation in Jan through May ‘04

Isolation II: Two-stage platform

- Stanford Engineering Test Facility Prototype characterization starting
- Initial dynamic measurements indicate that the design is a good success
- Instrumentation mounted
- Proposals for LASTI prototype structural design and fabrication due week of 8/25!



Suspension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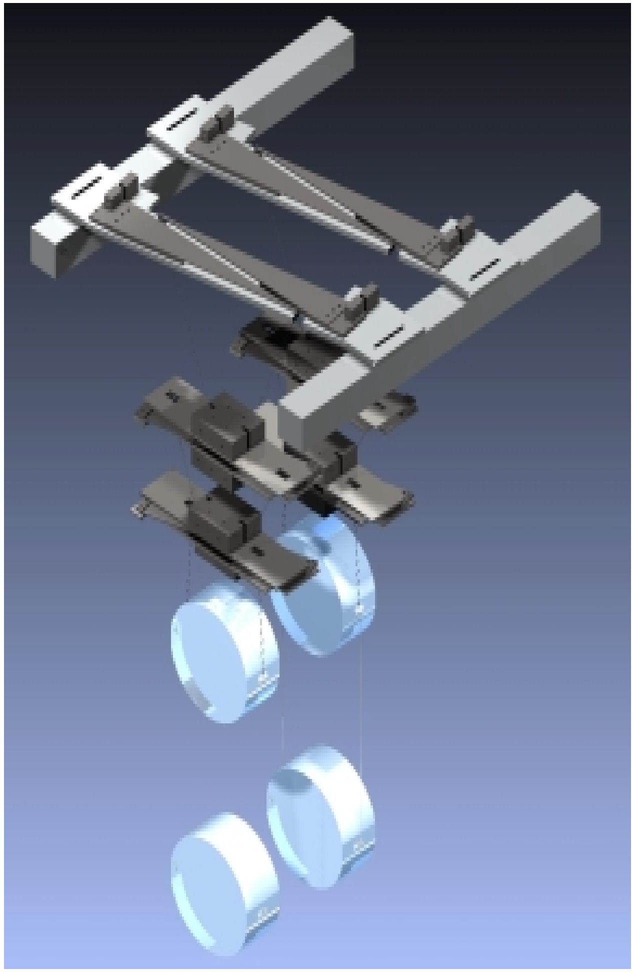
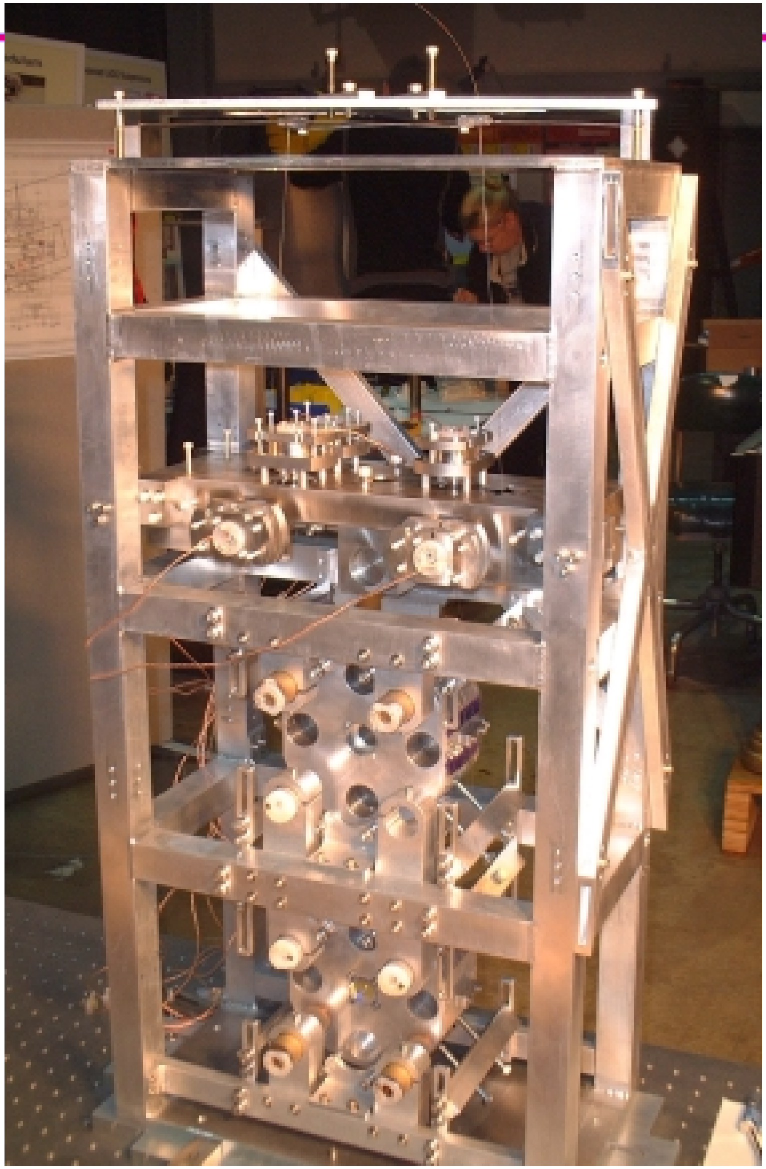
Suspensions I: Test Mass Quads

- Success of GEO600 a significant comfort
  - » All suspensions now installed
- PPARC support: significant financial and technical contribution; quad suspensions, electronics, and some sapphire substrates
  - » U Glasgow, Birmingham, Rutherford Appleton
- Updating of requirements and concept
  - » Choice of <10Hz bounce mode
- Intensive exchanges to bring new team members up to speed
  - » 4 day Glasgow meeting just concluded
- Studies of damping, actuation, clamping…

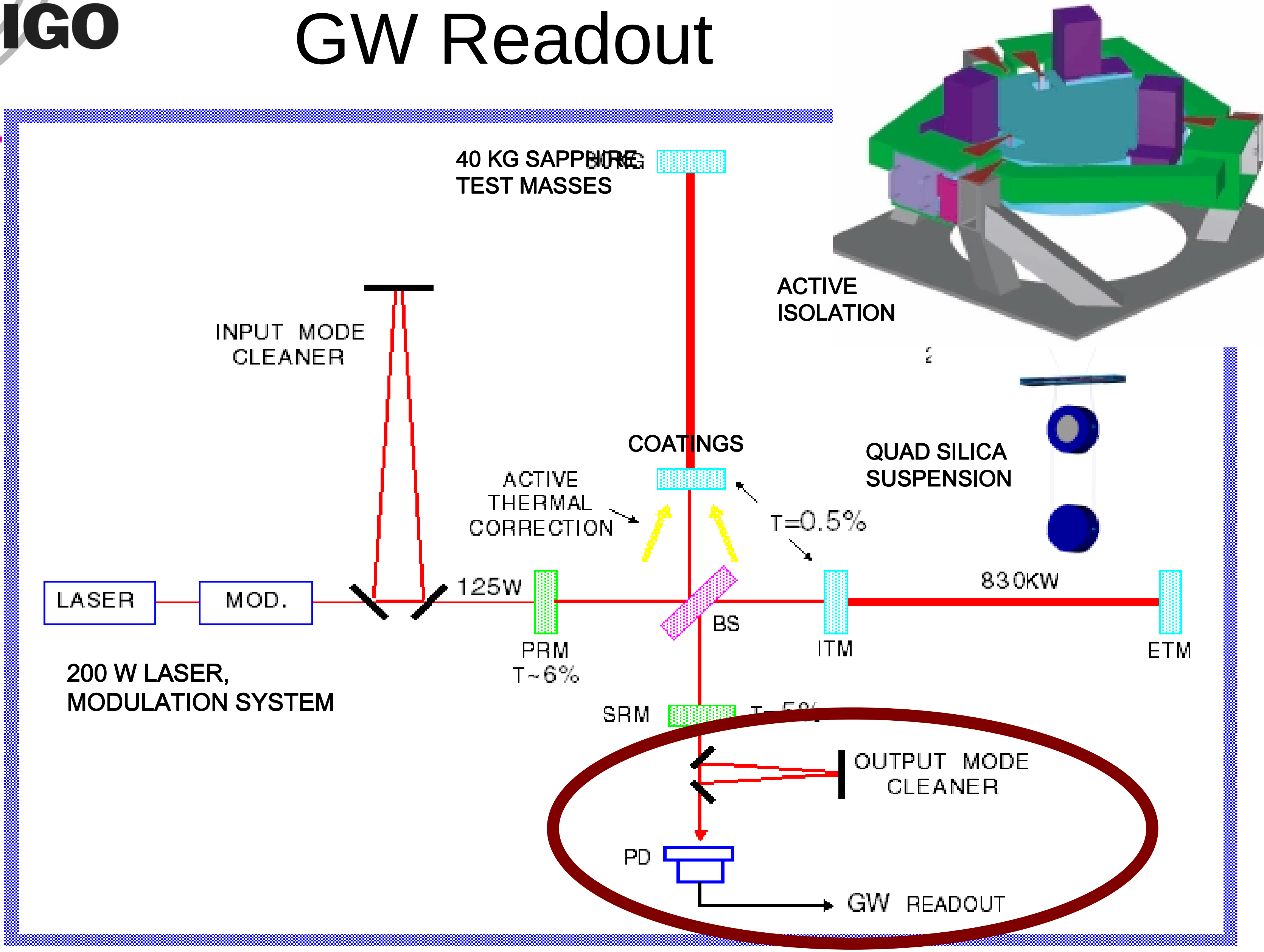


Suspensions II: Triples

- Prototype of Mode Cleaner triple suspension now complete
- In testing at Caltech, basic dynamics, damping
- OSEM design being refined
- To be installed in LASTI late 2003
- Recycling mirror design underway



GW Readout



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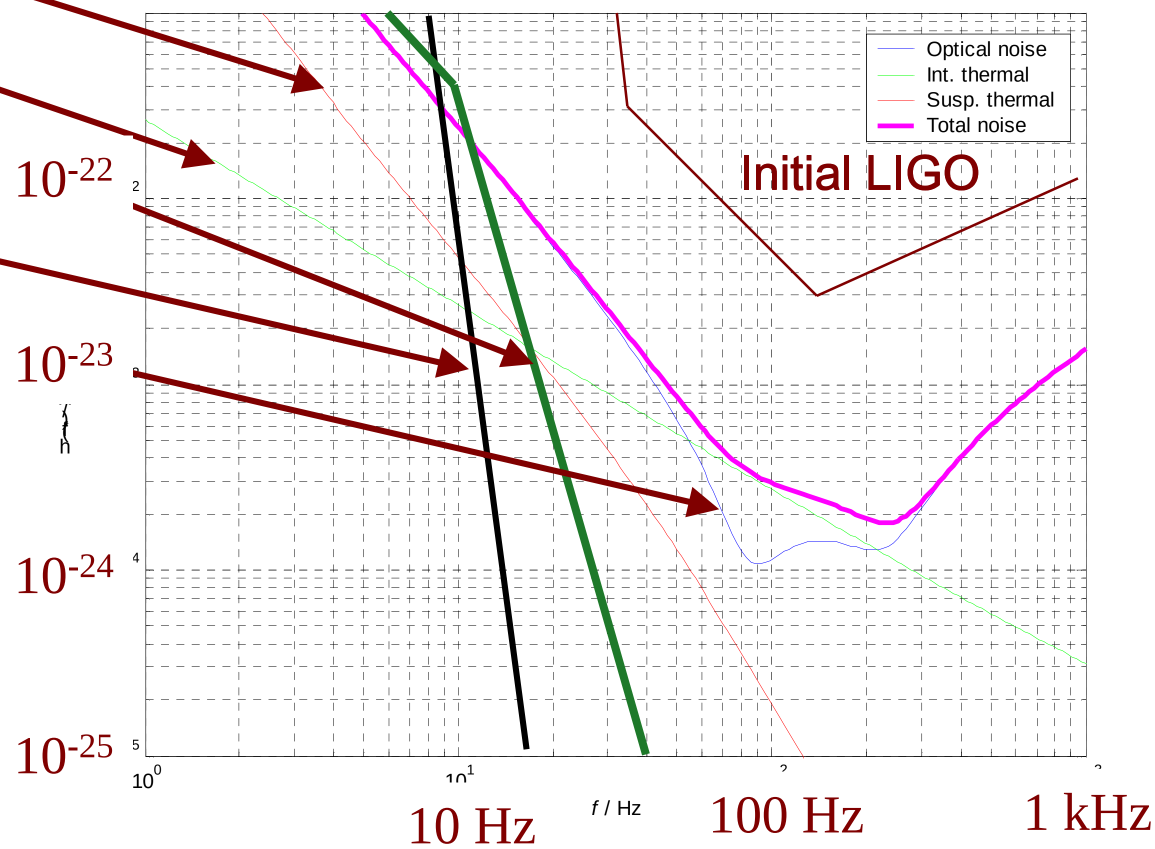
GW readout, Systems

- GEO-600 starting to lock with signal recycling (no cavities in arms, though)
- Glasgow 10m prototype
  - » SR experiment control matrix elements confirmed, near diagonal, fit models
- Caltech 40m prototype construction nearly complete, early testing
- Baseline strain readout chosen: DC fringe offset
  - » Allows other subsystem requirements to be set
- Tracking several efforts to improve on the baseline Adv LIGO sensing system (through upgrades, conceivably baseline changes if merited):
  - » Mesa beams which better fill mirrors, reduce thermal noise
  - » Variable-transmission signal recycling mirrors (ACIGA proposed contribution)
  - » Injection of squeezed vacuum into output port

Anatomy of the projected Adv LIGO detector performance

- Suspension thermal noise
- Internal thermal noise
- Newtonian background, estimate for LIGO sites
- Seismic 'cutoff' at 10 Hz
- Unified quantum noise dominates at most frequencies for full power, broadband tuning



- NS Binaries: for two LIGO observatories, 3 interferometers,
  - » Initial LIGO: ~20 Mpc
  - » Adv LIGO: ~350 Mpc
- Stochastic background:
  - » Initial LIGO: ~3e-6
  - » Adv LIGO ~3e-9

Proposal Status

- Submitted in March
- Proposal to NSF is $122 M; additional support from international partners (GEO and ACIGA), current and future LIGO Lab operating budget
  - » Subsystem leads LSU, GEO (UK, Hannover), UFlorida, ACIGA, Caltech, MIT
  - » Fiduciary responsibility is with the LIGO Lab
- Review in June
  - » Great support from LSC
  - » Useful for us technically
  - » Went quite well

Closeout Comments

- Advanced LIGO will provide the capability to observe a variety of astrophysical phenomena including inspiral events, continuous-wave sources, bursts, and stochastic backgrounds. Achievement of the design strain sensitivity (more than a factor of ten beyond Initial LIGO) is feasible and detection of events is plausible. Detection of any source would be a dramatic direct confirmation of the existence of gravitational waves and would have exciting and wide-ranging implications for gravitational physics, astrophysics, and our understanding of the universe.

- The committee agrees that the current state of the proposed project is at a sufficiently mature level that the process leading to construction should proceed. Although technical challenges remain, the plan for solving the technical problems appears sound and no major obstacles have been identified that would justify delaying the construction of Advanced LIGO.

Proposed Plan

- Initial LIGO Observation 2002 – 2006
  - » 1+ year observation within LIGO Observatory
  - » Significant networked observation with GEO, LIGO, TAMA, VIRGO
  - » No plans to make significant upgrades to Initial LIGO system
- Structured R&D program to develop technologies
  - » Cooperative Agreement carries R&D in Lab to Final Design, 2005
- Proposal submitted in March for fabrication, installation
- NSF review in June 2003
- First equipment money requested for 2005
  - » Sapphire Test Mass material, seismic isolation fabrication
  - » Prepare a ‘stock’ of equipment for minimum downtime, rapid installation
- Start installation in 2007
  - » Baseline is a staged installation, Livingston and then Hanford
  - » Two 4km instruments at Hanford, one 4km instrument at Livingston
- Start coincident observations in 2010