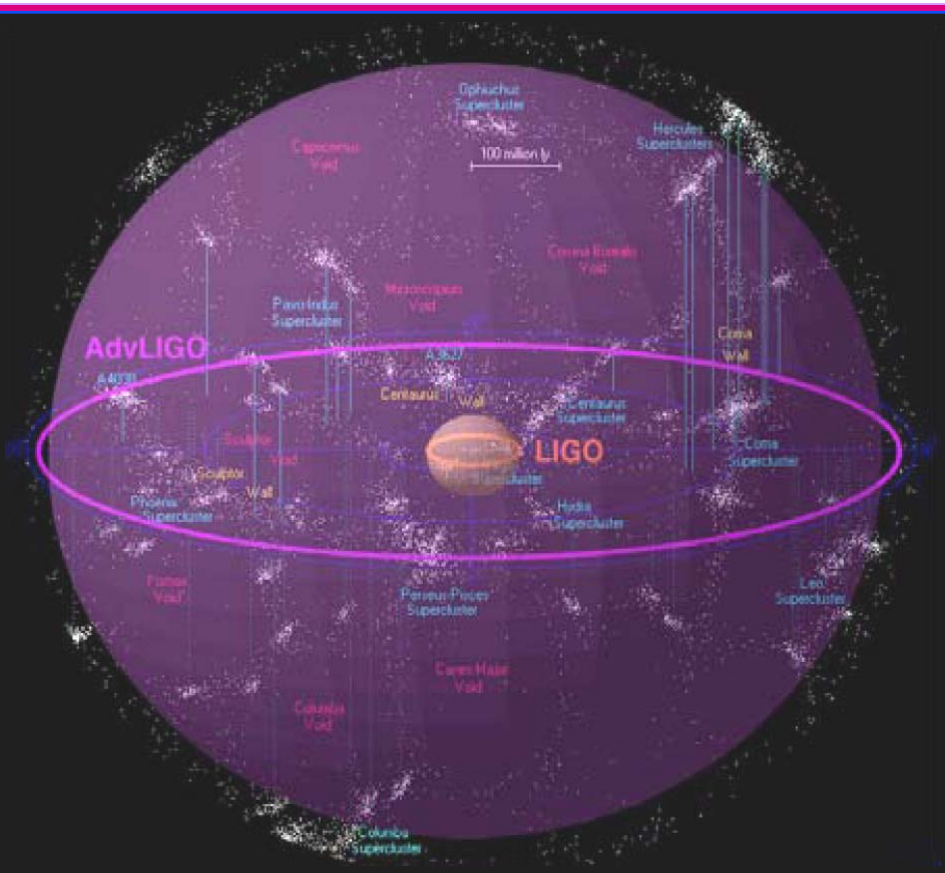
Advanced LIGO Status



LIGO Scientific Collaboration Meeting

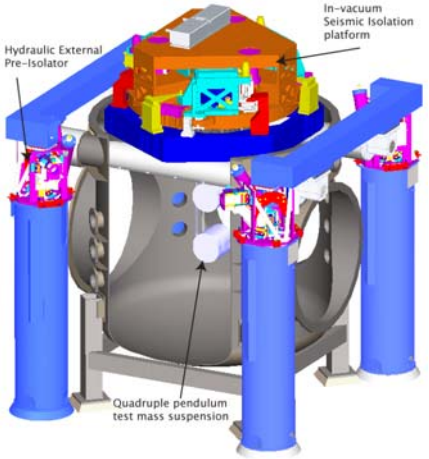
August 15, 2006 @LSU

Dennis Coyne

LIGO Laboratory, Caltech

Seismic Isolation (SEI) for the BSC Chamber

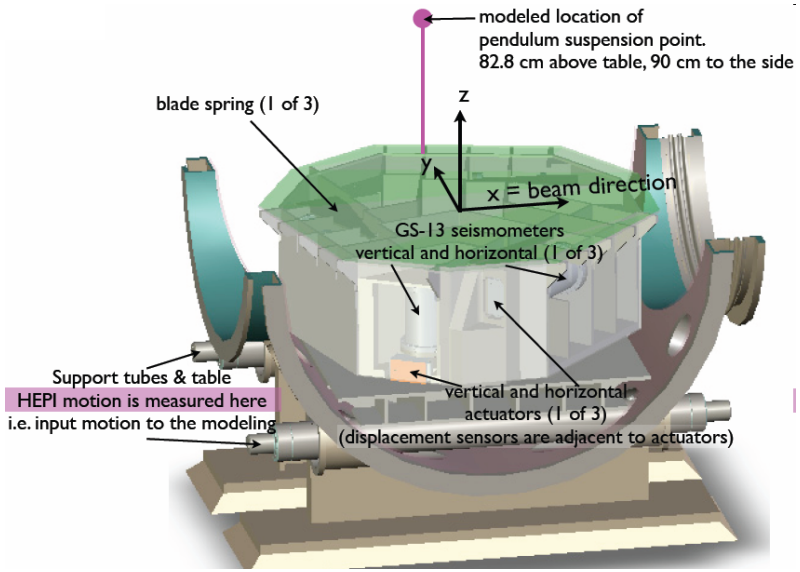
- **Assembly of the Two-Stage, Internal Seismic Isolation (ISI) is well underway at LASTI**
- **Expect 'dirty' assembly & testing completion this fall & clean assembly early 2007**
- **Joined to the "Noise" Prototype 2nd Quarter 2007**

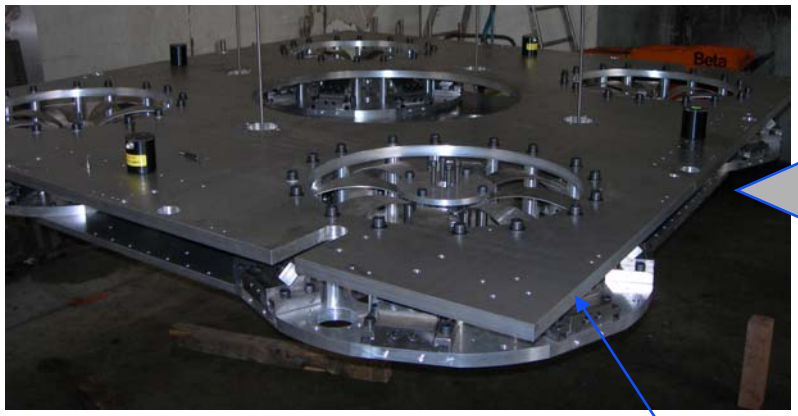


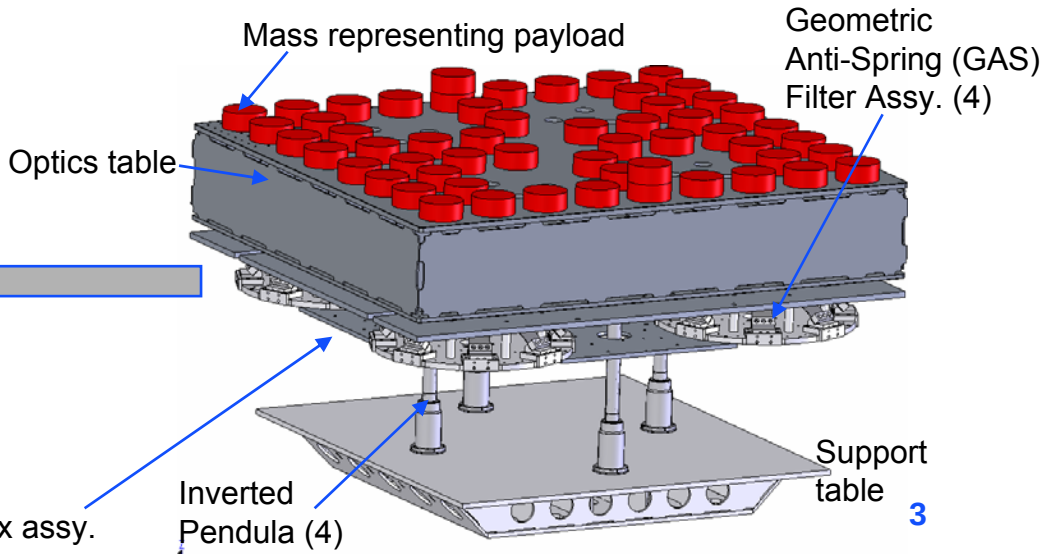
Requirement	HAM Chamber Value	BSC Chamber Value
Payload mass	510 kg	800 kg
Range	± 1 mm, ± 0.5 mrad	± 1 mm, ± 0.5 mrad
Optics table noise	4 x 10^{-11} m/√Hz (@10 Hz)	3 x 10^{-13} m/√Hz (@10 Hz)
Angular noise	100 nrad RMS	10 nrad RMS

Seismic Isolation (SEI) for the HAM Chamber

- Relaxed Seismic requirements established
- Baseline design approach
  - » Optimized (now single stage internal to vacuum system)
  - » Prototype conceptual design nearing completion; detailed design to start soon
- Alternative HAM-SAS approach
  - » Prototype fabrication expected to be completed October
  - » LASTI Experimental Results due by 4/2007
- Decision & AdL Prototype fabrication start 4/2007

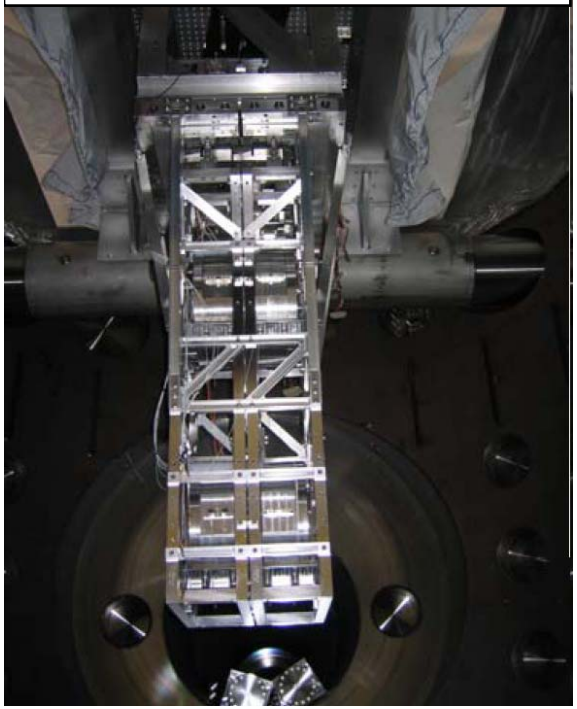






Suspensions
(Combined US and UK Effort)

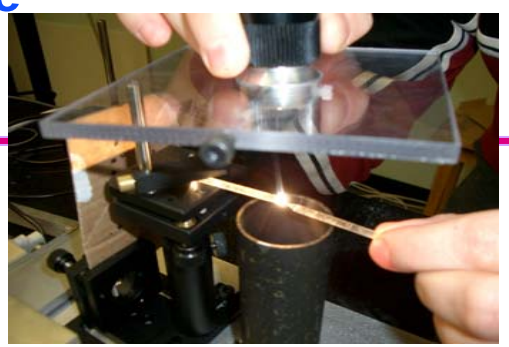
Quad Suspension in LASTI BSC Chamber



- **Test Mass (Quad) Suspension**
  - » **'Controls' Prototype installed at LASTI & under Test**
  - » **Preliminary Results in June for Concurrent "Noise" Prototype Development**
  - » **The UK Group delivers the "Noise" Prototype (close to final design) ~3/2007**
  - » **Installation ~5/2007**

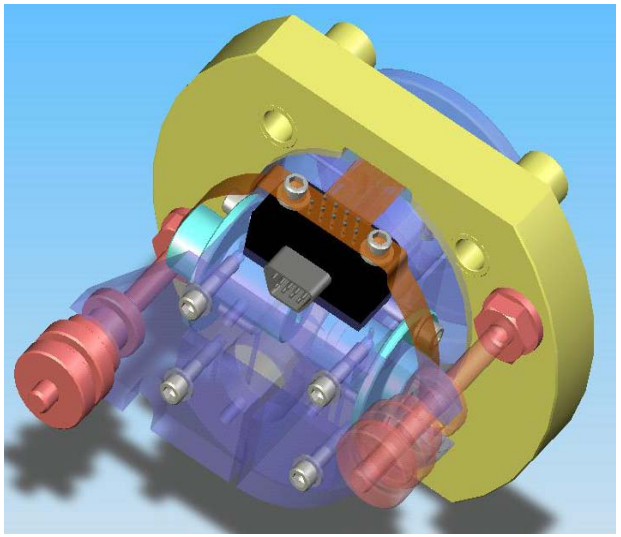
- **Other suspensions (extensions of existing designs):**
  - **Input Mode Cleaner mirror (triple) – prototype installed**
  - **Recycling mirror (triple) –full design**
  - **Beamsplitter (triple) –conceptual design**
  - **Folding Mirror (triple) –conceptual design**
  - **Output mode cleaner (double) –conceptual design underway - emphasis for Enhanced LIGO**
  - **Mode matching telescopes, steering mirrors etc (single)**

New Elements/Aspects of the "Noise" Prototype, Quadruple Suspension



Welding 3mm silica rod with 9W CO_2 laser

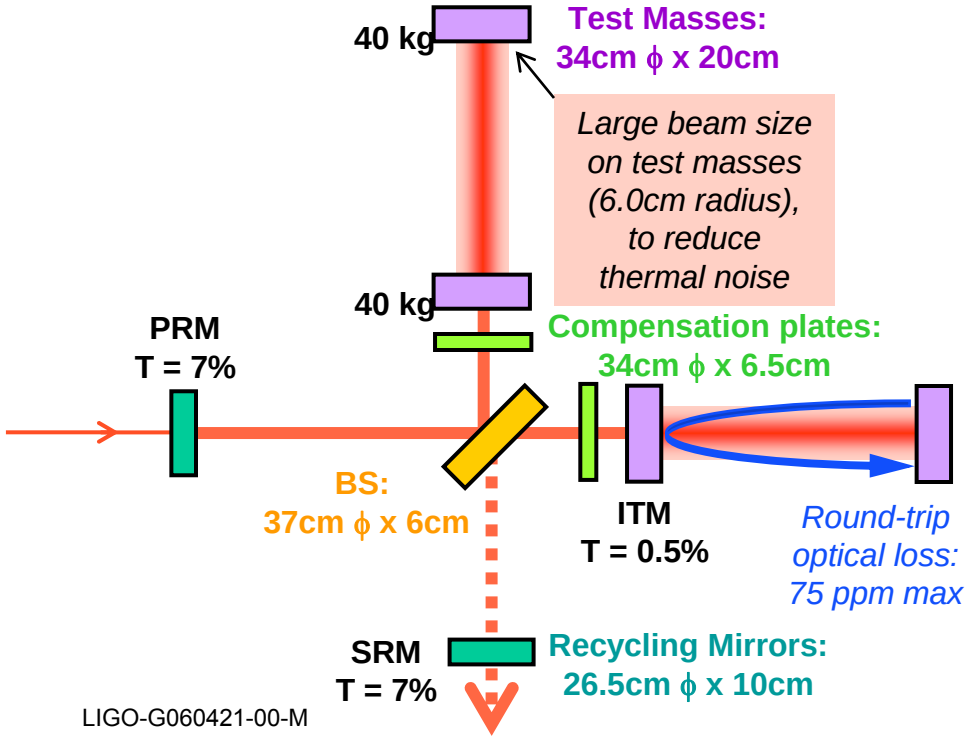
- **Silica Fiber/Ribbon Pulling**
  - » **R&D on computer controlled CO_2 laser system proceeding well**
  - » **Fibers up to 570 mm long, 184 ± 5 microns diameter (15 microns dia. repeatability)**
  - » **3 GPa breaking stress (factor of safety ≈ 4)**
- **Fiber/Ribbon Welding**
  - » **Fiber & ribbon welding demonstrated**
  - » **Working to improve welded strength**
- **Electronics**
  - » **Improved Optical Sensing & Electro-Magnetic actuator (OSEM) assembly**
  - » **New Control & Data Systems (CDS), Bus & Network Topology at LASTI implemented**
- **Motion Limiters ('earthquake stops')**
  - » **Fused silica contact tips, improved adjustment capability**



Modified Hybrid OSEM Design

Core Optics Components

- **Continuing coating R&D for lower mechanical and optical loss coatings**
  - » **Silica/Silica-doped titania shows reduced mechanical loss, but not likely as good as Silica/titania-doped tantala for optical properties**
  - » **Silica/Silica-doped tantala coatings are being tested currently**
  - » **LMA working on minimizing loss in Silica/titania-doped tantala**

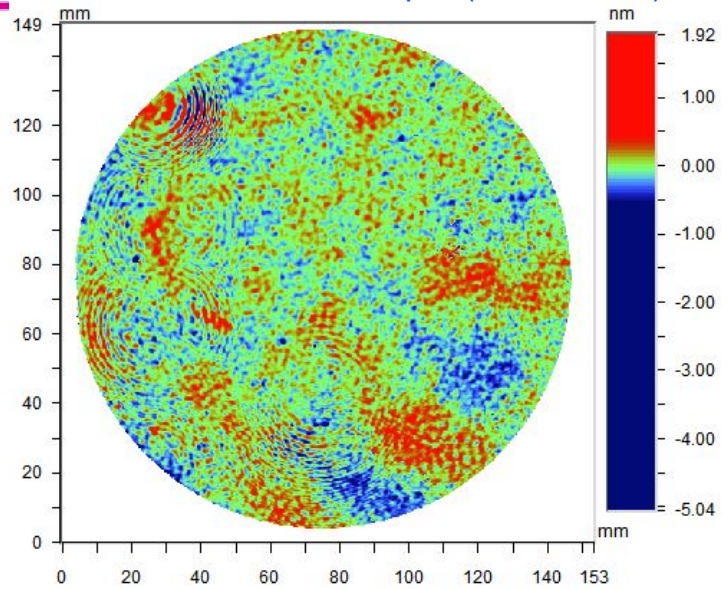


- **Substrate procurement**
- **Substrate polishing**
- **Dielectric coatings**
- **Metrology**

Core Optics Components

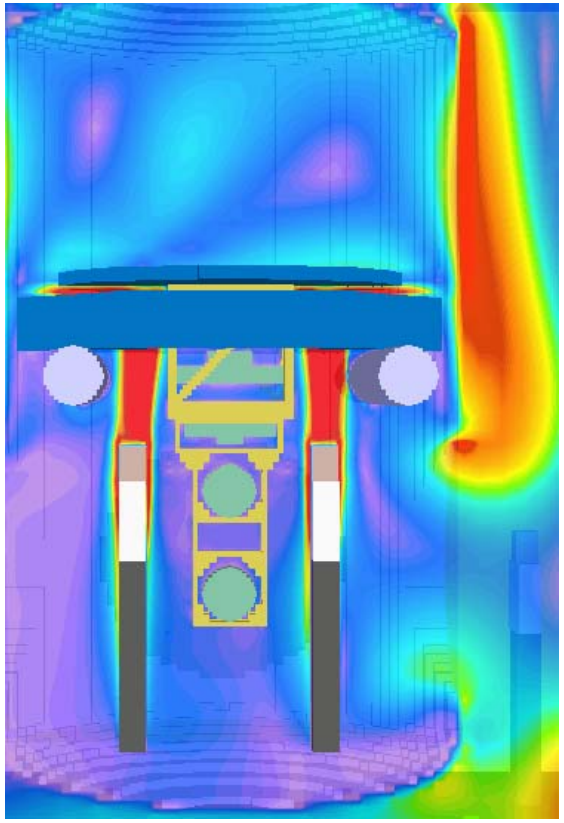
- **Polishing**
  - » Analysis of Radius-of-Curvature sensitivity
    - – FFT Optical Analysis code development to be completed ~Aug
    - – Will define ROC tolerance for nearly de-generate (baseline) and stable (alternative) recycling cavities for 'Pathfinder' effort
  - » Analysis of 'Orange Peel' residual polishing figure error suggests 2 ppm loss
  - » Analysis of surface figure PSD suggests ~0.5 nm rms required for 20 ppm loss budget
  - » Preparing 'Pathfinder' procurement specifications/bid-package to qualify polishing sources on larger optics
- **Scatter requires improvement over Initial LIGO levels**
  - » Exploring improved particulate cleanliness techniques/requirements
- **Electrostatic charging**
  - » Kelvin probe development underway (Trinity College)
  - » Commercial Kelvin probe purchase/development being investigated

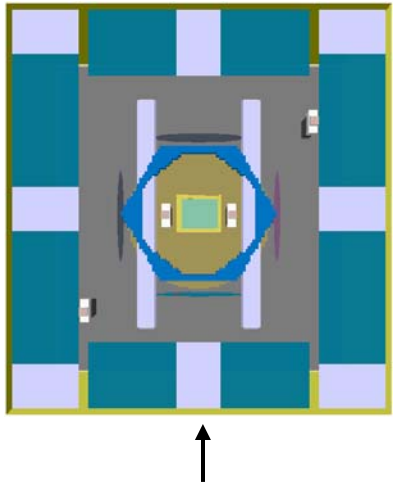
'orange peel' residual polishing error
In an Initial LIGO Core Optic (0.18 nm rms)

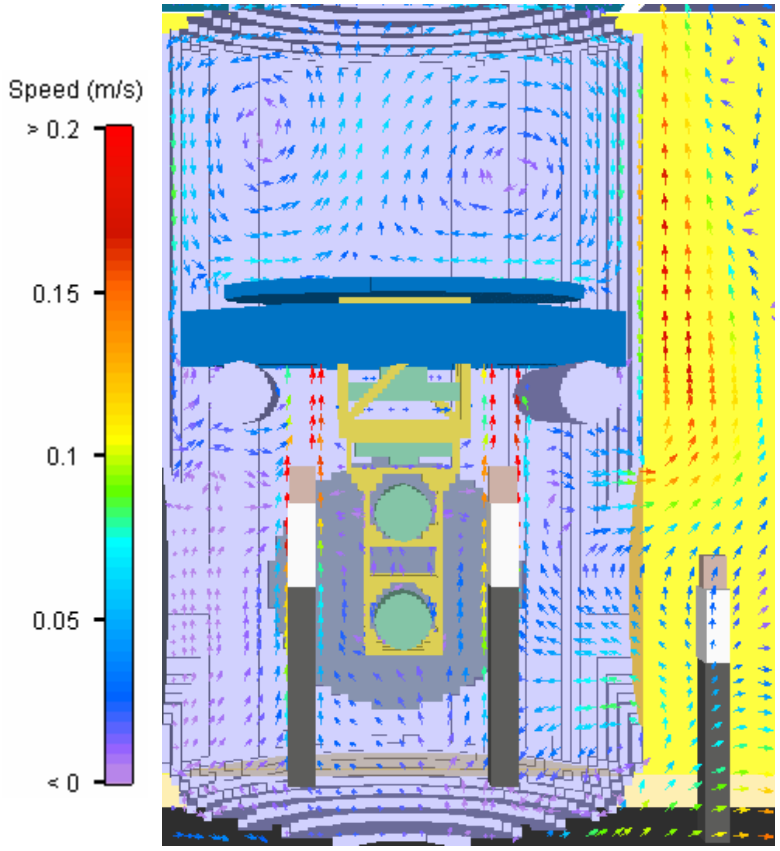


Requirements	
Surface figure	< 1 nm rms
Micro-roughness	< 0.1 nm rms
Coating absorption	< 0.5 ppm (required) < 0.2 ppm (goal)
Coating scatter	< 2 ppm (required) < 1 ppm (goal)
Coating mechanical loss	< 2 x 10^{-4} (required) < 3 x 10^{-5} (goal)

Chamber Airflow Profile – Preliminary Computational Fluid Dynamics Simulation (Flomerics Inc.)





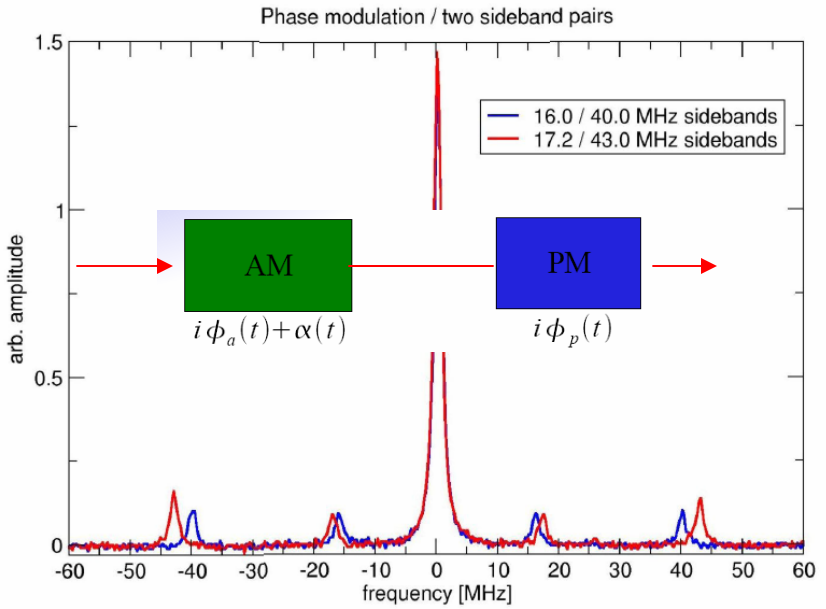


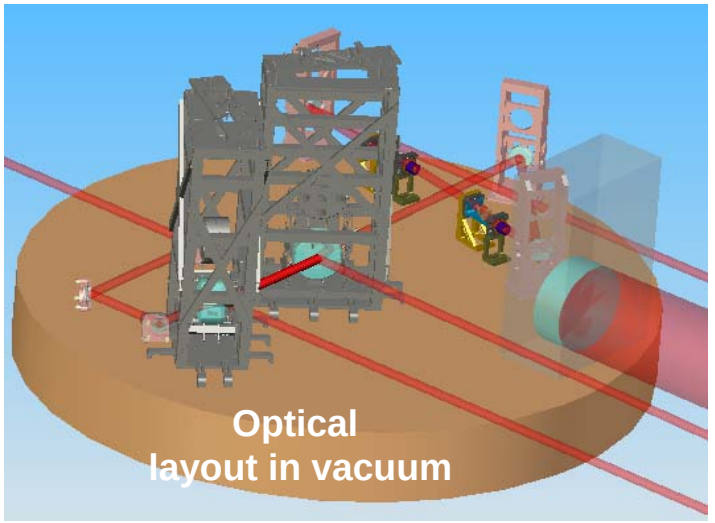
We see that when the supply and exhaust in the chamber are turned off natural convection caused by the workers dominates the airflow patterns

Plane taken at centerline of the chamber

Input Optics

- Preliminary Design for Advanced LIGO Isolators and Modulators held in April
- Modulation
  - » Mach-Zehnder modulation
    - – set-up converted to high power
    - – ΔL Requirements derived
  - » **Complex Modulation**
    - – **Cross-product free SB synthesis done**
- Power Control
  - » High power beam dump developed
- Mode Cleaner
  - » MC design finesse reduced from 2000 to 500
    - – Based on PSL pointing performance
    - – Reduced thermal effects
- Faraday Isolator
  - » Characterization of angular drifts at 100 W
  - » Vacuum testing starting
    - – Second generation housing needed
- Adaptive Mode Matching Telescope
  - » Examination of MMT incorporation into stable power recycling cavity

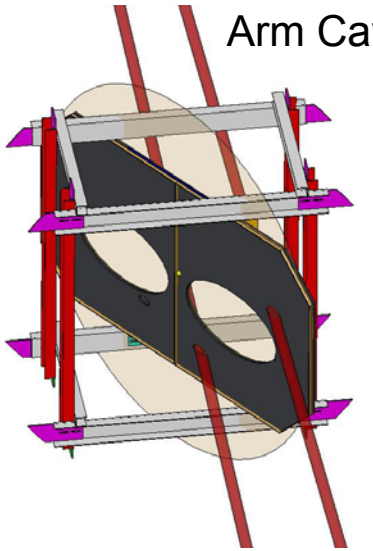




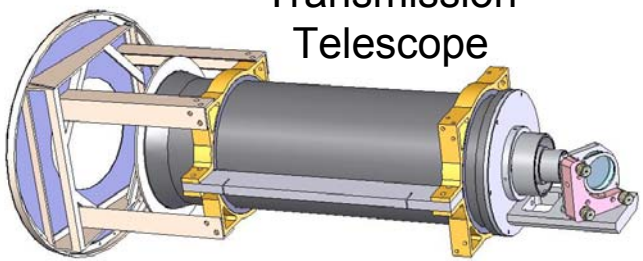
Auxiliary Optics & Thermal Compensation System

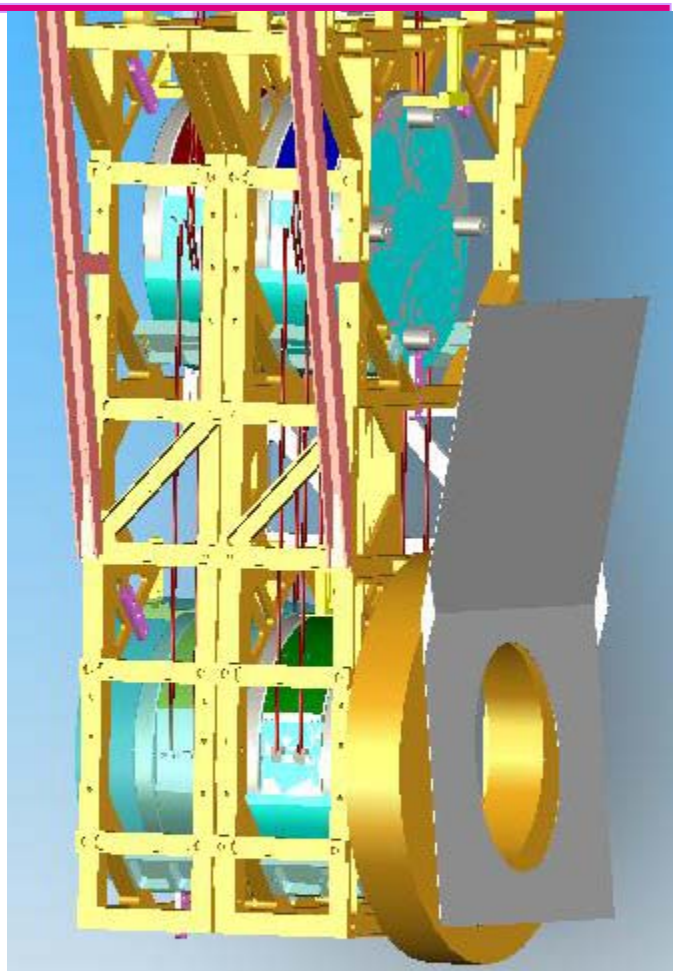
- **AOS & TCS Preliminary Designs proceeding well**
  - » **Thermal Compensation Review to be held this Thursday**
  - » **AOS review this fall**
- **Thermal compensation testing on the quad to be incorporated into the LASTI program**

Arm Cavity Baffle



ETM Transmission Telescope

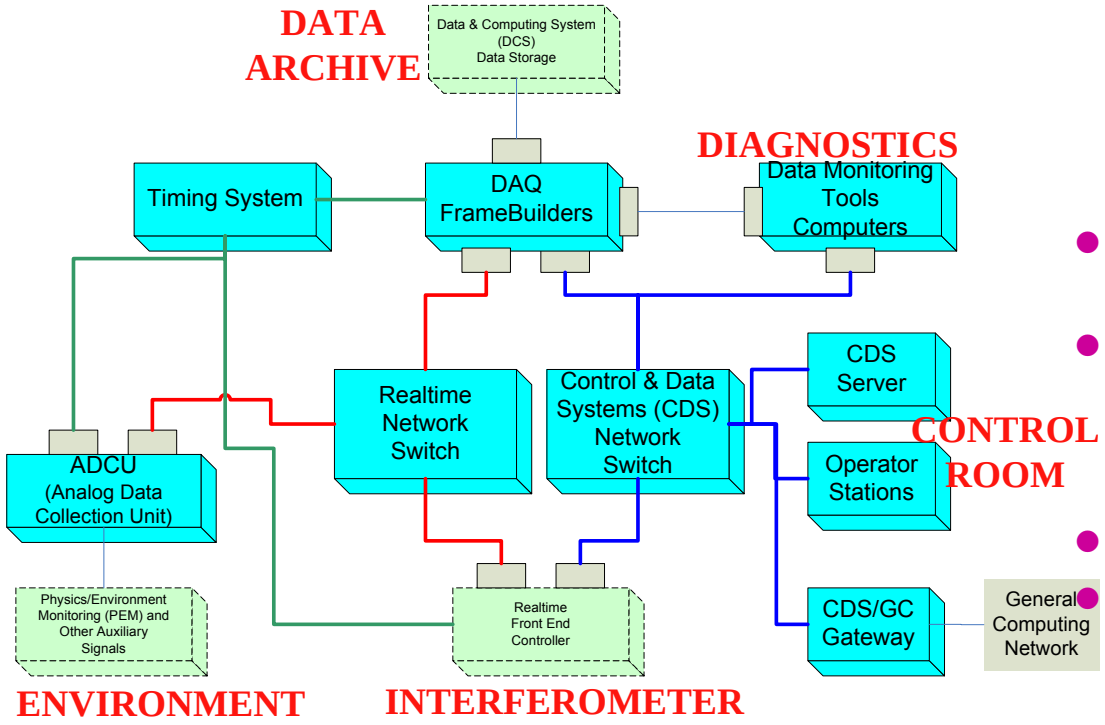




TCS Ring heater & Recycling Cavity Baffle on ITM Quad

Control & Data System

- **Prototype PCI-X System**
  - » **Completed Installation at LASTI for Suspension Testing**
  - » **Balance of infrastructure & seismic support installation is in-process**

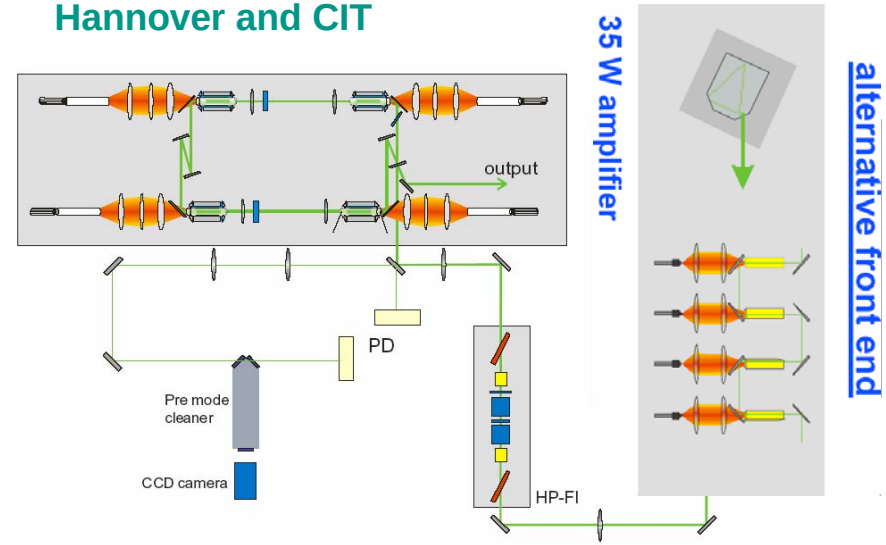


- **New Realtime Network Topology**
  - » **Star fabric vs Serial loop**
  - » **Deterministic GigE/PCIe from ADC/DAC I/O chassis to computers**
- **PCIe and custom ADC/DAC I/O**
- **Multi-CPU computers**
  - » **Arbitrary Waveform Generator (AWG) and Test Point Manager (TPM) built in**
  - » **EPICS interface via CPU memory instead of networked**
- **Supports higher infrastructure data rates (to 128 kHz)**
- **Realtime Linux Testing**
  - » **Previous systems use vxWorks**
  - » **Move away from Solaris for Framebuilders and operator stations**
- **New Timing System tests**
- **Generation of realtime code from Matlab model files**
  - » **LASTI quad & HEPI systems have code automatically generated from Matlab model files**

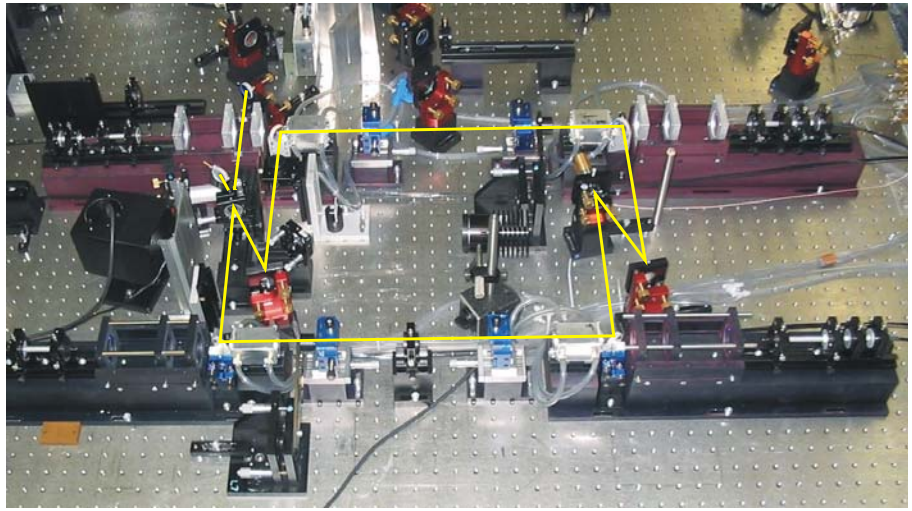
Pre-Stabilized Laser

- Proceeding well on the preliminary design
- Started bench prototype

Max-Planck Institute, Hannover leads the PSL development, working with Laser Zentrum Hannover and CIT



- Laser Achieved
  - 180W output power
  - Good spatial profile
  - Power fluctuations close to reqmnts
- PSL Achieved:
  - Frequency noise requirement
  - RIN=3 x 10^{-9}/sqrt(Hz) above 20 Hz (in table top experiment)
  - Diagnostic breadboard in final design phase

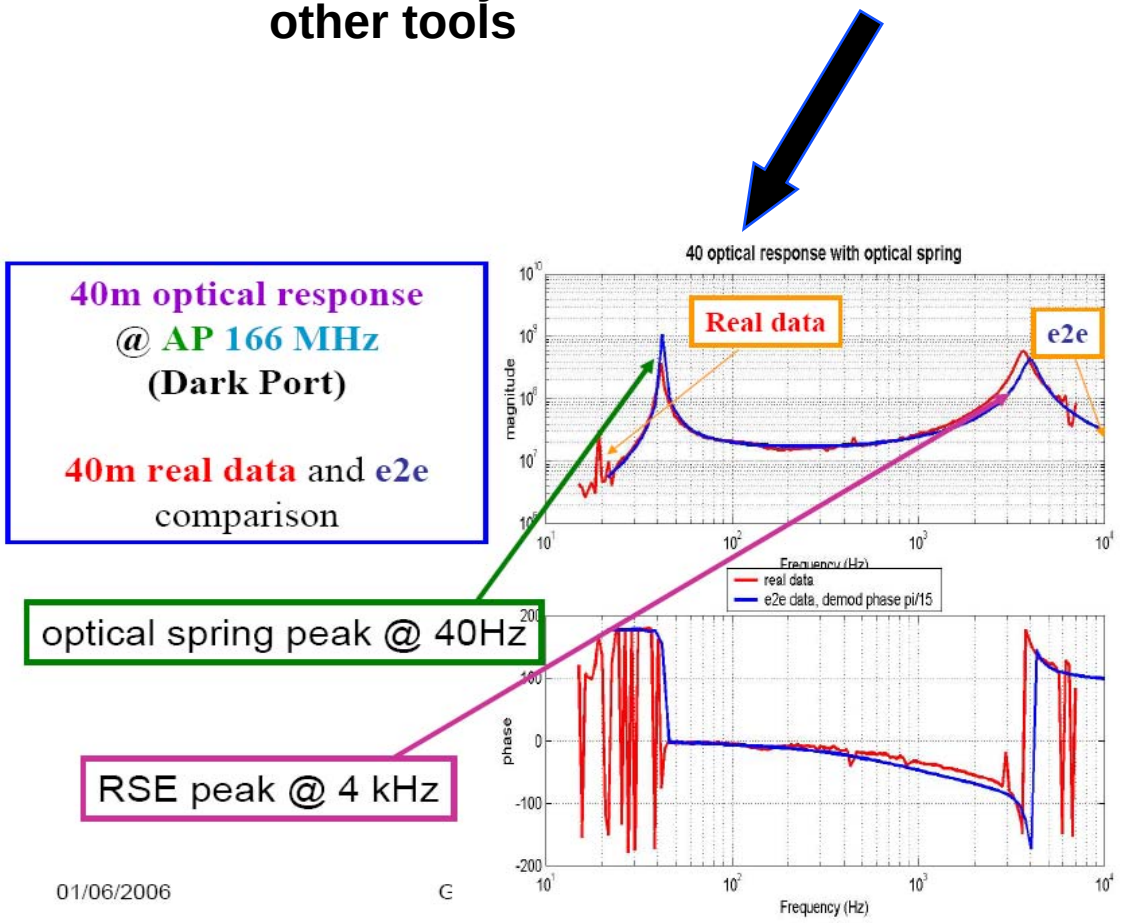


Injection locked 180W Laser Prototype

Interferometer Sensing & Controls

- **Continuing 40M work:**
  - **DC readout system with Output Mode Cleaner expected in place by late Aug**
  - **“Deterministic locking” works well with power recycled interferometer. To be applied to dual recycled interferometer, soon.**
  - **Testing new PCIx data acquisition architecture for the readout.**

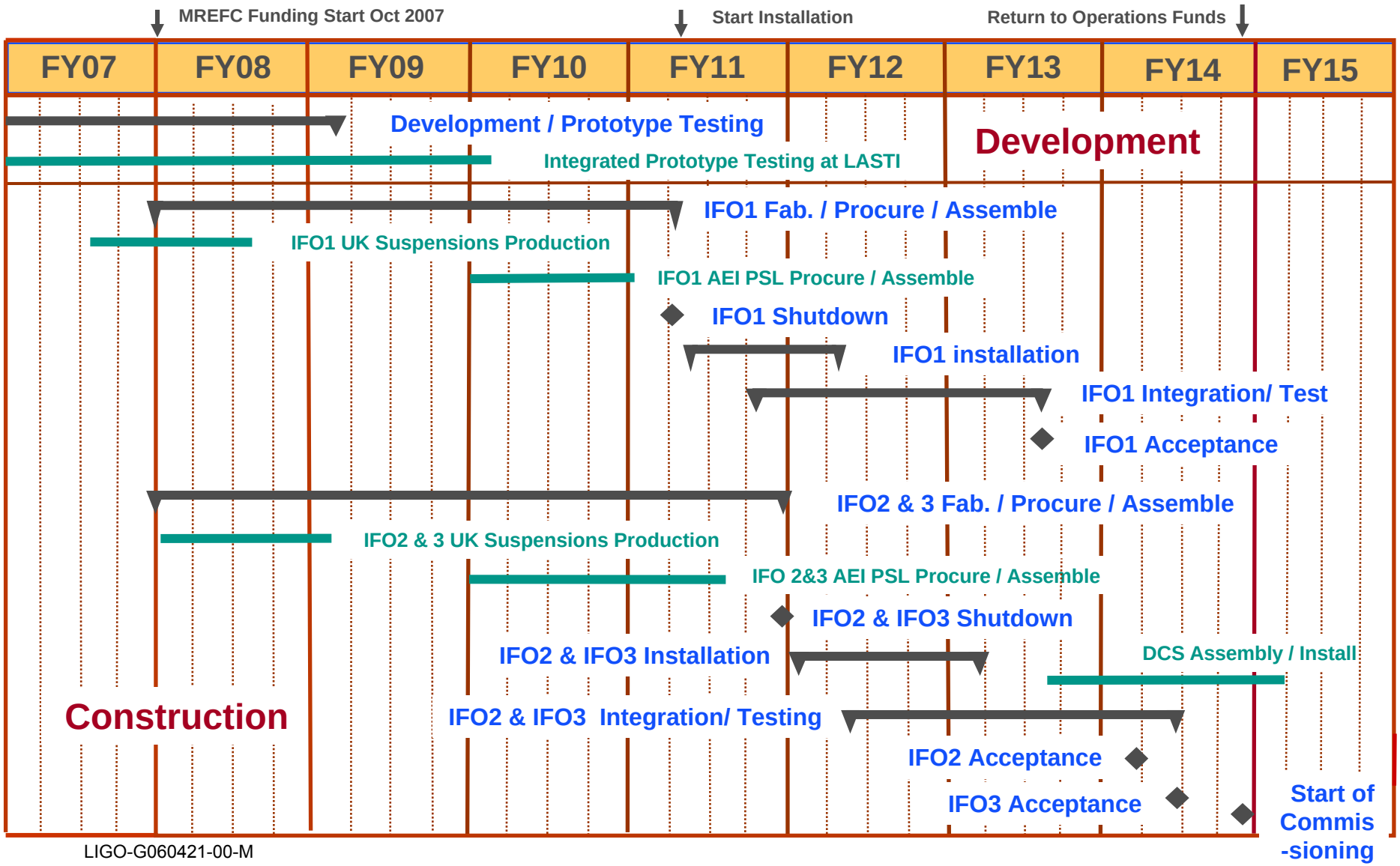
- **Pursuing early deployment of a DC readout & OMC suspension for Enhanced LIGO (2007)**
- **Modeling angular alignment sensitivity & control with E2E and other tools**



Project Baseline

- **Successful NSF Review of cost and schedule for AdL Project held 5/31-6/2**
  - » **Baseline review ~5/2007**
- **Issued Project Execution Plan (PEP), Risk Management Plan, Revised & reviewed Cost & Schedule**

Advanced LIGO Schedule Summary Cartoon



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Summary

- R&D proceeding reasonably well
  - » a little behind schedule, but recoverable and not threatening readiness for AdL construction funds
  - » Staffing limited in most cases (except coating R&D)
- Need to begin to staff up
  - » Accelerate development
  - » Anticipation of Adv. LIGO project funding start in FY08
- Completion of the pacing R&D efforts to be ready for AdL construction funds will be a challenge in the coming ~2 years
- Successful NSF Review of Advanced LIGO proposed cost & schedule!