40m Laboratory Upgrade Progress Report

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40m Technical Advisory Committee
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Primary objective: full engineering prototype of optics control scheme for a dual recycling suspended mass IFO, as close as possible to the Advanced LIGO optical configuration and control system

Advanced LIGO technical innovations tested at 40m

- **a seventh mirror for signal recycling**
  - » length control goes from 4x4 to 5x5 MIMO
- **detuned signal cavity (carrier off resonance)**
- **pair of phase-modulated RF sidebands**
  - » frequencies made as low and as high as is practically possible
  - » unbalanced: only one sideband in a pair is used
  - » double demodulation to produce error signals
- **short output mode cleaner**
  - » filter out all RF sidebands and higher-order transverse modes
- **offset-locked arms**
  - » controlled amount of arm-filtered carrier light exits asym. port of BS
- **DC readout of the gravitational wave signal**

Much effort to ensure high fidelity between 40m and Adv.LIGO!

Differences between AdvLIGO and 40m prototype

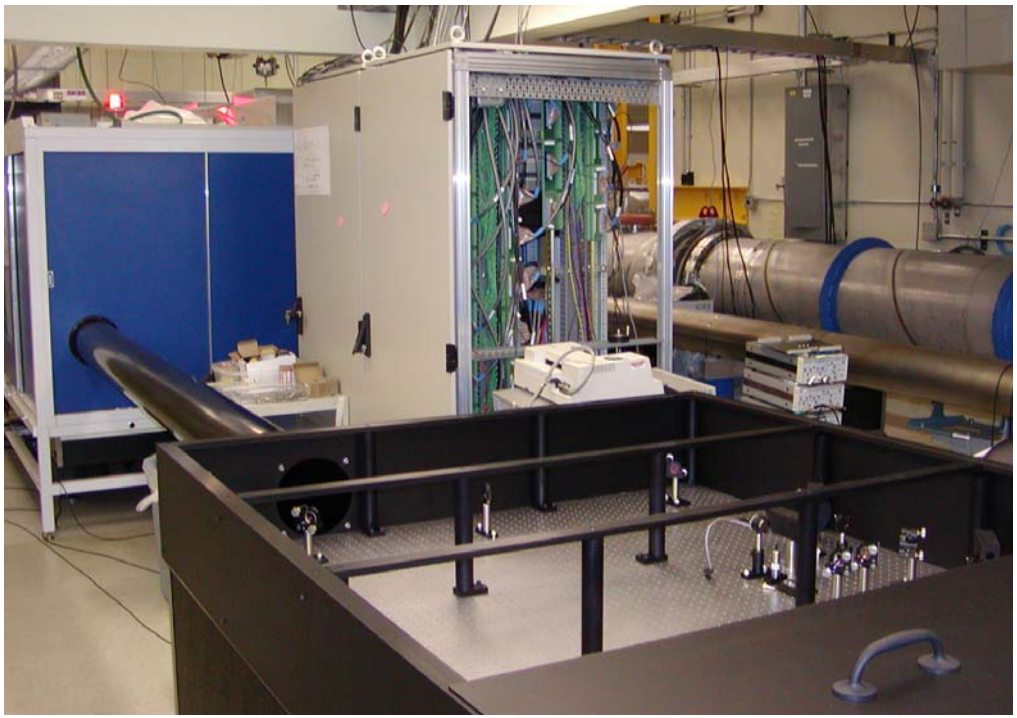
- **Initially, LIGO-I single pendulum suspensions will be used**
  - **No room for full scale AdvLIGO multiple pendulums – to be tested at LASTI**
  - **Scaled-down versions to test controls hierarchy in 2004?**
- **Only commercial active seismic isolation**
  - **STACIS isolators in use on all test chambers, providing ~30 dB of isolation from 1-100 Hz**
  - **No room for anything like full AdvLIGO design – to be tested at LASTI**
- **LIGO-I 10-watt laser, negligible thermal effects**
  - **Other facilities will test high-power laser (LASTI, Gingin)**
  - **Thermal compensation also tested elsewhere**
- **Small (5 mm) beam spot at TM's; stable arm cavities**
  - **AdvLIGO will have 6 cm beam spots, using less stable cavities**
  - **40m can move to less stable arm cavities if deemed useful**
- **Arm cavity finesse at 40m chosen to be = to AdvLIGO**
  - **Storage time is x100 shorter**
  - **significant differences in lock acquisition dynamics, in predictable ways**
- **Control RF sidebands are 36/180 MHz instead of 9/180 MHz**
  - **Due to shorter PRC length**
  - **Less contrast between PRC and SRC signals**

Milestones Achieved as of March LSC Meeting

- **Building renovation:** Control room added; electronics racks, power conditioners, cable trays, computers & networking infrastructure installed
- **Vacuum revision:** 13m MC and OOC added to envelope; pumps, controls updated
- **Active seismic isolation (STACIS)** installed at all test mass chambers
- **Initial LIGO PSL** commissioned and characterized; NPRO replaced and realigned
- **DAQ** installed and logging frames; trends saved since July 2001
- **PEM** installed and running (dust, seismometer, weather, STACIS readback)
- **Conceptual Design Review** completed in Oct 2001
- **Optical layouts complete** for in- and out-of-vacuum; parts lists assembled
- **Procurement** of CDS, ISC, etc. begun
- **Mode cleaner optics and suspensions** in hand, specs for core optics completed

Further Infrastructure

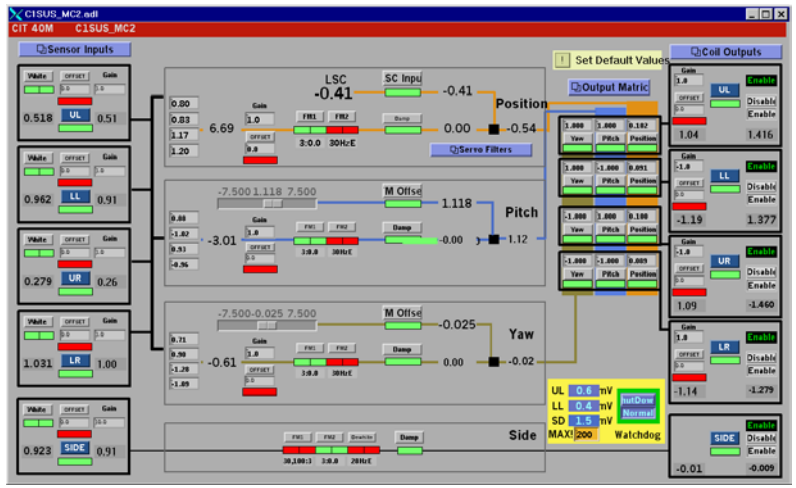
- Final optical table, beam tubes, table covers installed
- MC reflected and transmitted optical paths assembled
- IR-coated viewports, cameras installed

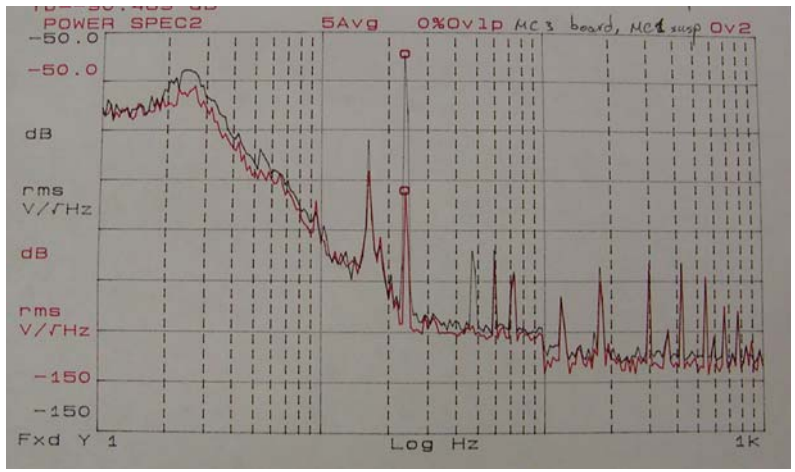


- MC, OOC seismic stacks installed and cabled
- MC optics hung, balanced, installed in April

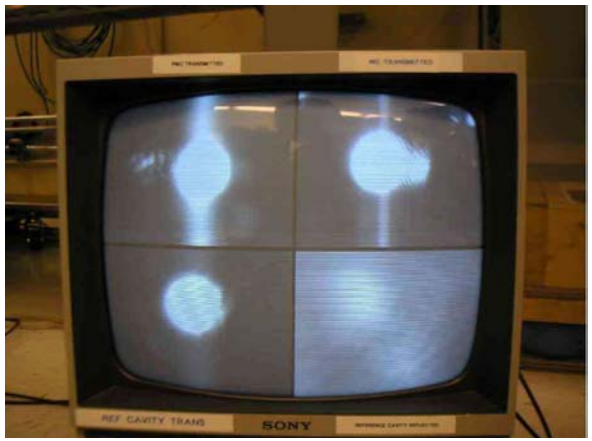
Digital Suspensions

- Digital suspensions for the mode cleaner optics were installed in May; full control system for all 10 core optics expected by end of 2002
- Digital notch filter added at 23.7 Hz to eliminate anomalous “roll mode” in MC1; may be due to lateral misalignment of OSEMs
- GDS/DTT/AWG installed; used Mark Barton’s code to diagonalize input, output matrices of MC2, MC3

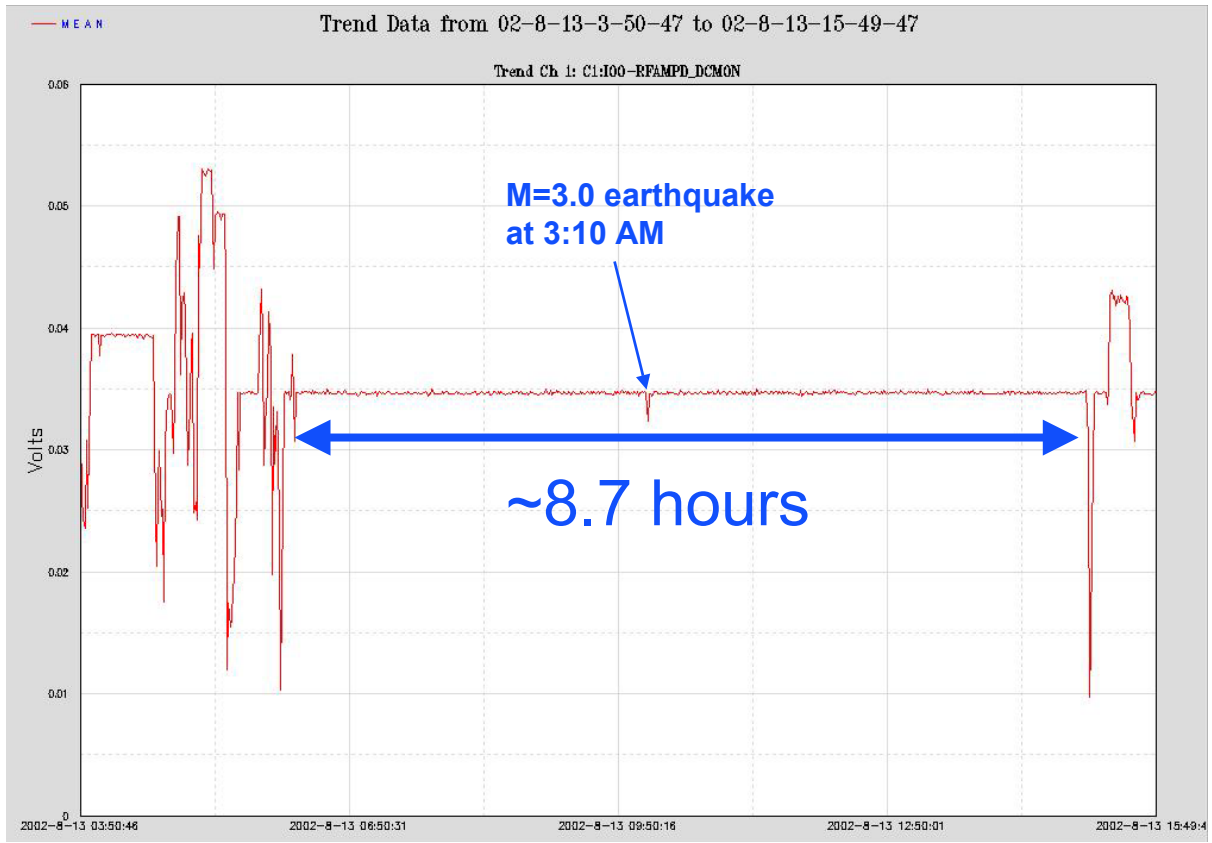




13-meter Mode Cleaner Lock



Lock has been achieved using an SR560 preamplifier in place of the MC servo VCO path. The SR560 is set to a 0.1-1 Hz bandpass with very high gain (70 dB).



LIGO

Core Suspended Optics

- The core optics for the main dual recycled interferometer were produced, polished, and coated as of Aug 2002. Completed pieces have been delivered and are being measured by LIGO optical engineers.

- The mechanical suspensions for the remaining 7 optics, for the main dual recycled interferometer, have been designed, fabricated, cleaned and baked.

- We plan to assemble the suspensions, hang the remaining 7 optics, and install them in the vacuum envelope in the fall of 2002.

LIGO

Alignment Sensing

- SURF Marcus Benna has studied the WFS alignment signals for 40m and AdvLIGO.
- He studied ModalModel, but could not succeed in making it work reliably for dual recycling.
- He wrote his own, compact Mathematica calculation, comparing against Twiddle for DC fields, and ModalModel for Initial LIGO alignment sensing.
- He finds that the sensing configuration (lengths, RF sidebands, pattern of resonances) which were designed for good length sensing, are NOT good for alignment sensing.

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(as in Initial LIGO).
elp; more f_2 at bright port gives some Δ(ITM) signal there.

gives some Δ(ITM) signal there.

SURF 2002

- Surjeet Rajendran, Caltech
  - » Analysis of coincident burst data
- Marcus Benna, Cambridge University
  - » Dual recycled AdvLIGO Alignment sensing
- David Bonfield, Cambridge University
  - » Mode Cleaner servo tuning and characterization
- Ilya Berdnikov, Cornell University
  - » Digital suspension controller characterization
- Aya Sekido, Tokyo University
  - » Mode matching and characterization of IOO

LIGO

Next 9 months

- Install alignment sensing and control on 13m mode cleaner.
- Fully characterize 13m mode cleaner performance.
- The digital suspension controllers for all 10 suspended optics should be complete by the end of calendar 2002.
- Assemble, hang, and install the seven core suspended optics (PRM, SRM, BS, ITMx, ETMx, ITMy, ETMy) by the end of calendar 2002, and have them damped by the controller system.
- Fabricate and install all remaining optical sensing equipment on the existing enclosed optical tables, by 2Q 2003.

LIGO

Next 9 months

- Fabricate and install auxiliary optics systems: scattered light control, initial alignment system, optical levers, video monitoring.
- Fabricate and install the length sensing and control system.
- Fabricate and install the alignment sensing and control system.
- Data handling: fiber link to CACR? (Currently, we only save all trend frames, backed-up to AIT occasionally).
- There may be some necessary augmentation of the DAQS, computing, networking, and environmental monitoring systems.

LIGO

Longer term

- All systems installed, commissioning begun by summer 2003.
  - » First experiments in dual recycled configuration response, lock acquisition, and control are expected to take at least a year.
  - » We expect that LSC members, as well as students, will participate in this most interesting phase of the project.

- Elements not designed in detail will be delayed until FY04:
  - » Output mode cleaner
  - » DC demodulation scheme
  - » Multiple suspensions?

LIGO

Milestones revisited

- **2Q 2002:**
  - **All in-vacuum cables, feedthroughs, viewports, seismic stacks installed.**
  - **12m input MC optics and suspensions, and suspension controllers.**
- **3Q 2002:**
  - **Begin commissioning of 12m input mode cleaner.**
  - **Acquisition of most of CDS, ISC, LSC, ASC.**
- **4Q 2002:**
  - **Core optics (early) and suspensions ready. Ten Suspension controllers. Some ISC.**
  - **Glasgow 10m experiment informs 40m program**
  - **Control system finalized**
- **2Q 2003:**
  - **Core optics (late) and suspensions ready.**
  - **auxiliary optics, IFO sensing and control systems assembled.**
- **3Q 2003: Core subsystems commissioned, begin experiments**
  - **Lock acquisition with all 5 length dof's, 2x6 angular dof's**
  - **measure transfer functions, noise**
  - **Inform CDS of required modifications**
- **3Q 2004: Next round of experiments.**
  - **DC readout. Multiple pendulum suspensions?**
  - **Final report to LIGO Lab.**

(Some) outstanding issues and action items (40m, AdvLIGO)

- **Any significant changes in people's thinking re: optical configuration, controls, CDS architecture??**
- **180 MHz PD's for WFS, LSC. Double demodulation(180 ⊕ 36 MHz).**
- **Develop ASC model with ModalModel.**
- **Design servo filters for LSC, ASC!**
- **Detailed noise model (RSENOISE, Jim Mason)**
- **Lock acquisition studies with E2E/DRLIGO. Develop lock acquisition algorithms, software.**
- **Triple-check thermal effects (Melody) – negligible?**
- **Output mode cleaner – will PSL-PMC-like device be adequate? (For 40m, for AdvLIGO). Suspended?**
- **Offset-lock arms - algorithms, software.**
- **DC GW PD – in vacuum? Suspended?**