Caltech 40m Lab Update

LSC Meeting Baton Rouge

Mar 21, 2007

Robert Ward, Caltech

and the 40m team:

Rana Adhikari, Benjamin Abbott, Rich Abbott, Rolf Bork, Tobin Fricke, Valery Frolov, Keisuke Goda, Jay Heefner, Alexander Ivanov, Osamu Miyakawa, Kirk McKenzie, Royal Reinecke, Bram Slagmolen, Michael Smith, Robert Taylor, Stephen Vass, Sam Waldman,

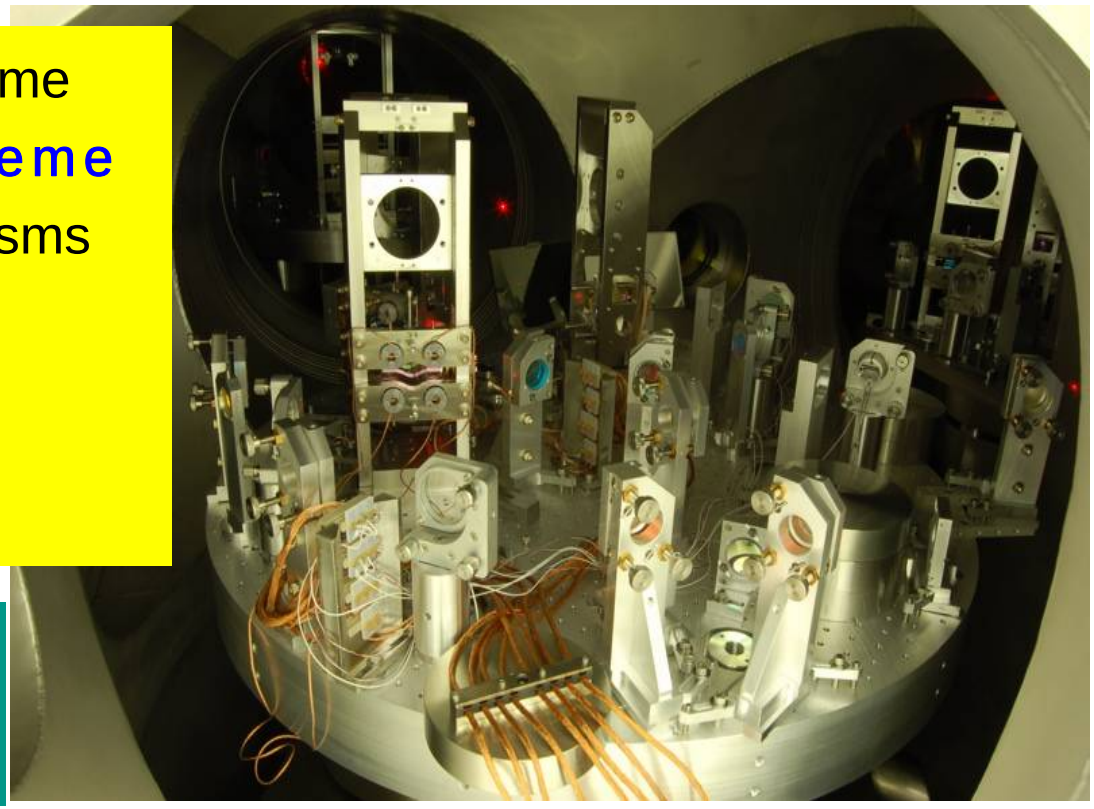
and Alan Weinstein

Caltech 40 meter prototype interferometer (*mini*-LIGO)

Objectives

- Develop **lock acquisition procedure** of detuned Resonant Sideband Extraction (RSE) interferometer, as close as possible to AdLIGO optical design

- Test/Characterize **LSC** scheme
- Develop DC readout scheme
- Characterize noise mechanisms
- Test ***QND techniques***
- Develop/Test ASC scheme
- Testbed for AdLIGO *controls technologies*



Prototyping will yield crucial information about how to build and run AdLIGO (and eLIGO).

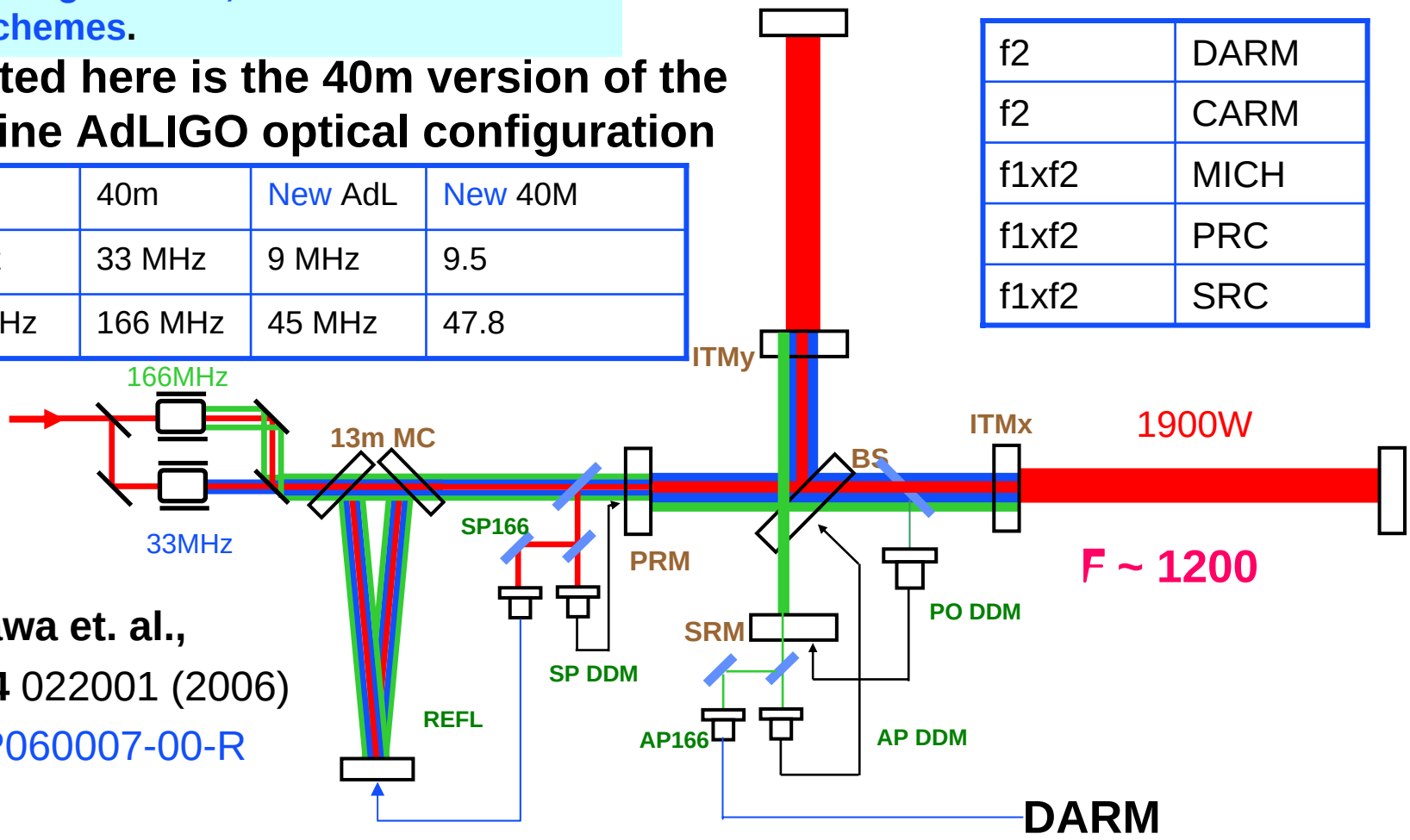
AdLIGO: Detuned RSE

We can operate the 40m in multiple configurations, with various control schemes.

Depicted here is the 40m version of the baseline AdLIGO optical configuration

	AdL	40m	New AdL	New 40M
f1	9MHz	33 MHz	9 MHz	9.5
f2	180MHz	166 MHz	45 MHz	47.8

f2	DARM
f2	CARM
f1xf2	MICH
f1xf2	PRC
f1xf2	SRC



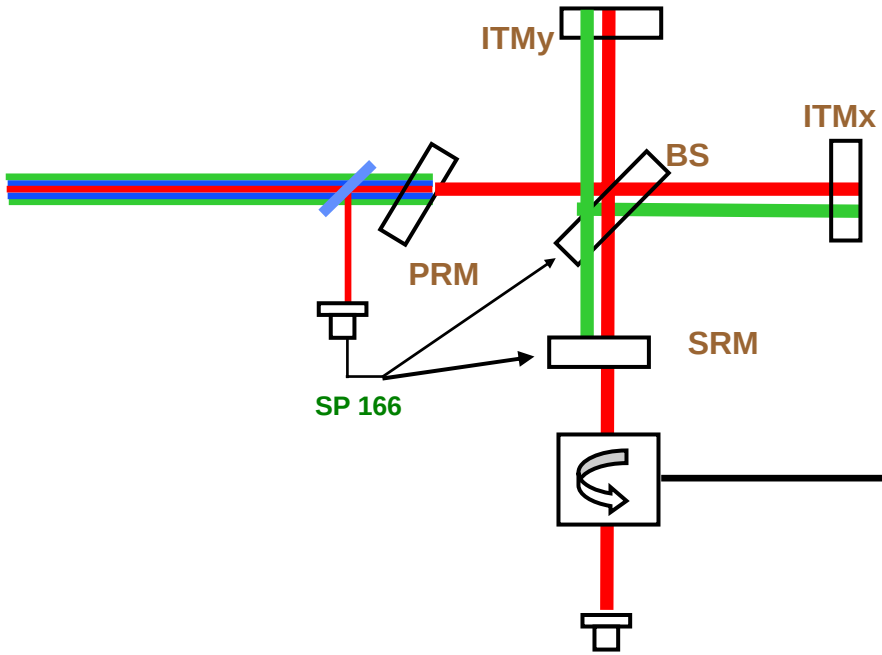
Miyakawa et. al.,

PRD 74 022001 (2006)

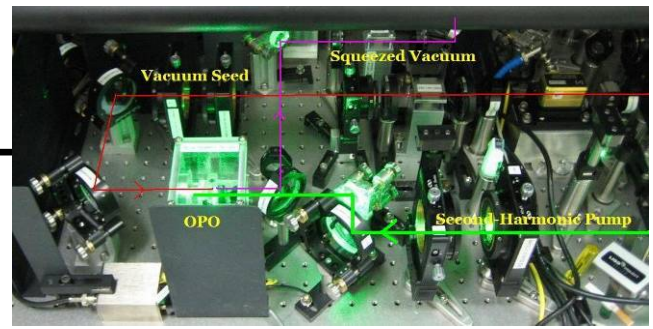
LIGO-P060007-00-R

QND: Squeezing Enhanced SRMI

misalign ETMs and PRM to get a signal-recycled michelson



SQUEEZER

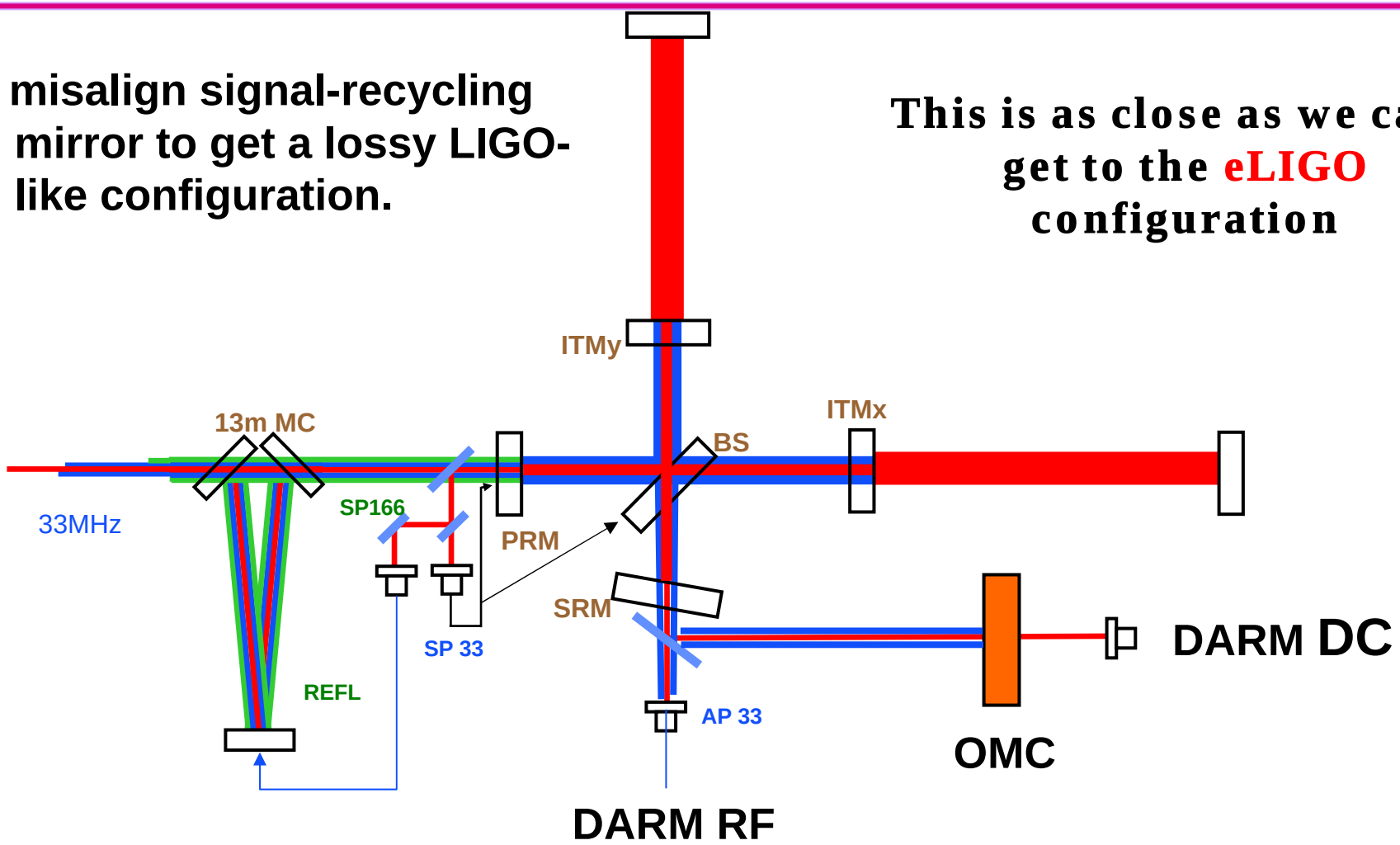


Homodyne Detector

eLIGO: Power Recycled Fabry Perot Michelson

misalign signal-recycling mirror to get a lossy LIGO-like configuration.

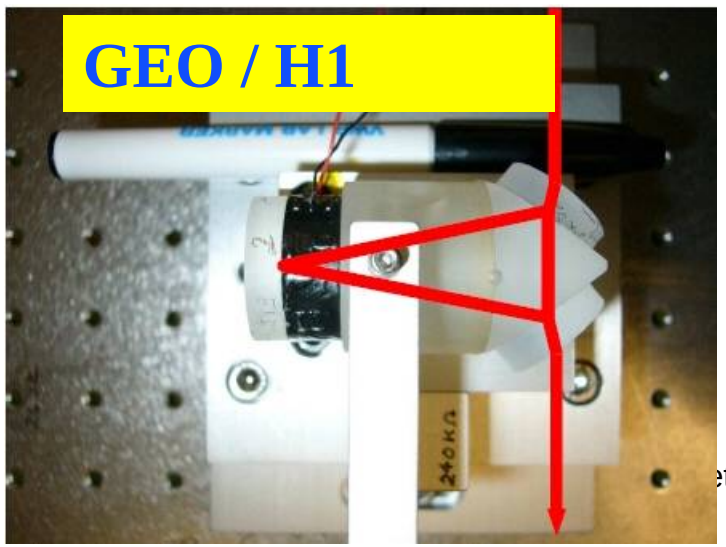
This is as close as we can get to the eLIGO configuration

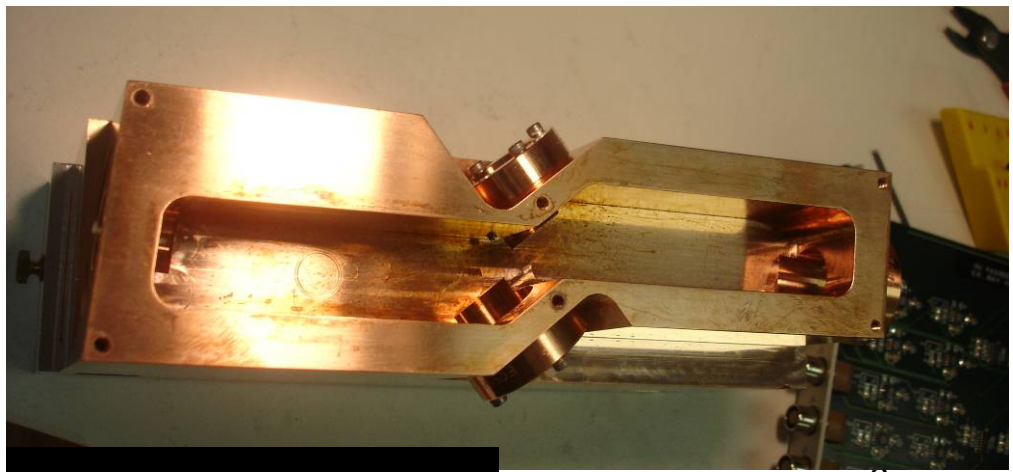


Better Signal Detection: Output Mode Cleaner

Basic Motivations

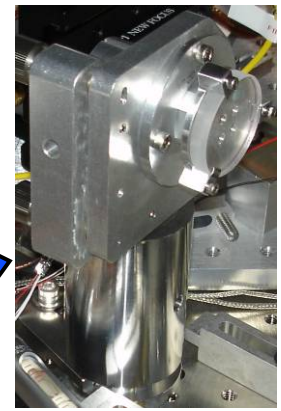
- Limited by photodetector saturations; OMC removes most of the junk light
- Removing the junk light reduces shot noise
- DC Readout (AdvLIGO baseline) has technical noise benefits:
  - Optical gain increase (field overlap)
  - RF Oscillator phase noise (significant at ~few kHz)
  - Laser frequency noise (close to limiting)
- Past OMC testing on H1 showed benefits, but was ~300x too noisy
- Critical for any high power operations (H2 only uses 2.5 W of laser power)





DC Readout components

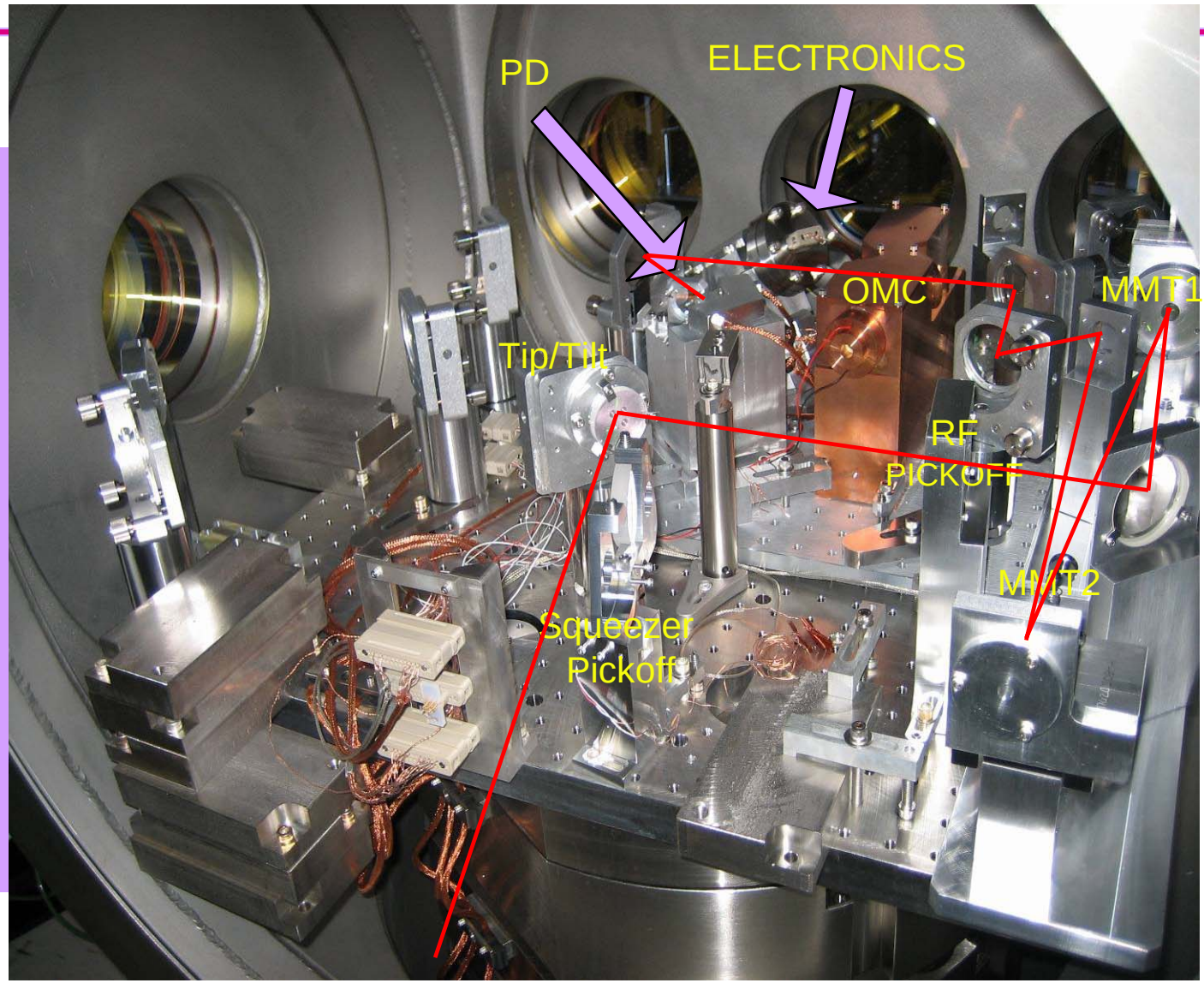
- **Output Mode cleaner**
  - » Four-mirror design, 48 cm round-trip length
  - » Finesse 210; transmission 92%; loss 0.1% round trip
  - » PZT length actuation; dither-lock at ~12 kHz
- Two in-vac PZT tip-tilt steering mirrors
  - » Steer the IFO output into the output mode cleaner



- Mode-matching telescope (picomotor focus control)
- **IN-VACUUM PHOTODETECTOR**
  - » 2mm InGaAs diodes, with an amplifier/whitening circuit in a can.
- **AdLIGO-style PCIX system for digital control (CDS)**
  - » Front-end code auto-generated from simulink drawing (Borkspace)
  - » 32 kHz real time control (Rest of 40m is 16kHz)
  - » Interfaced to existing VME-based RFM network

OMC/DC Readout Installation

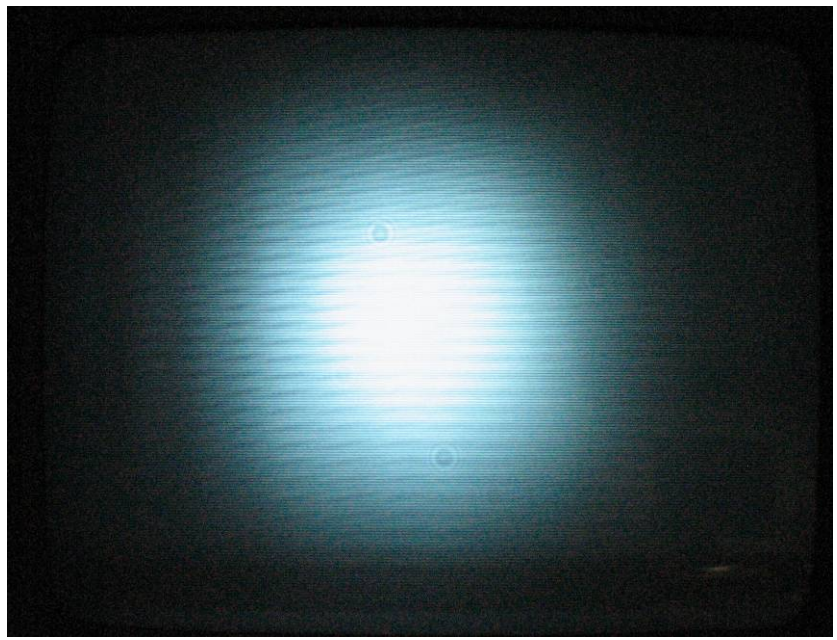
- DC Readout Beamline Installed September 2006
- Electronics+ Software installed October 2006



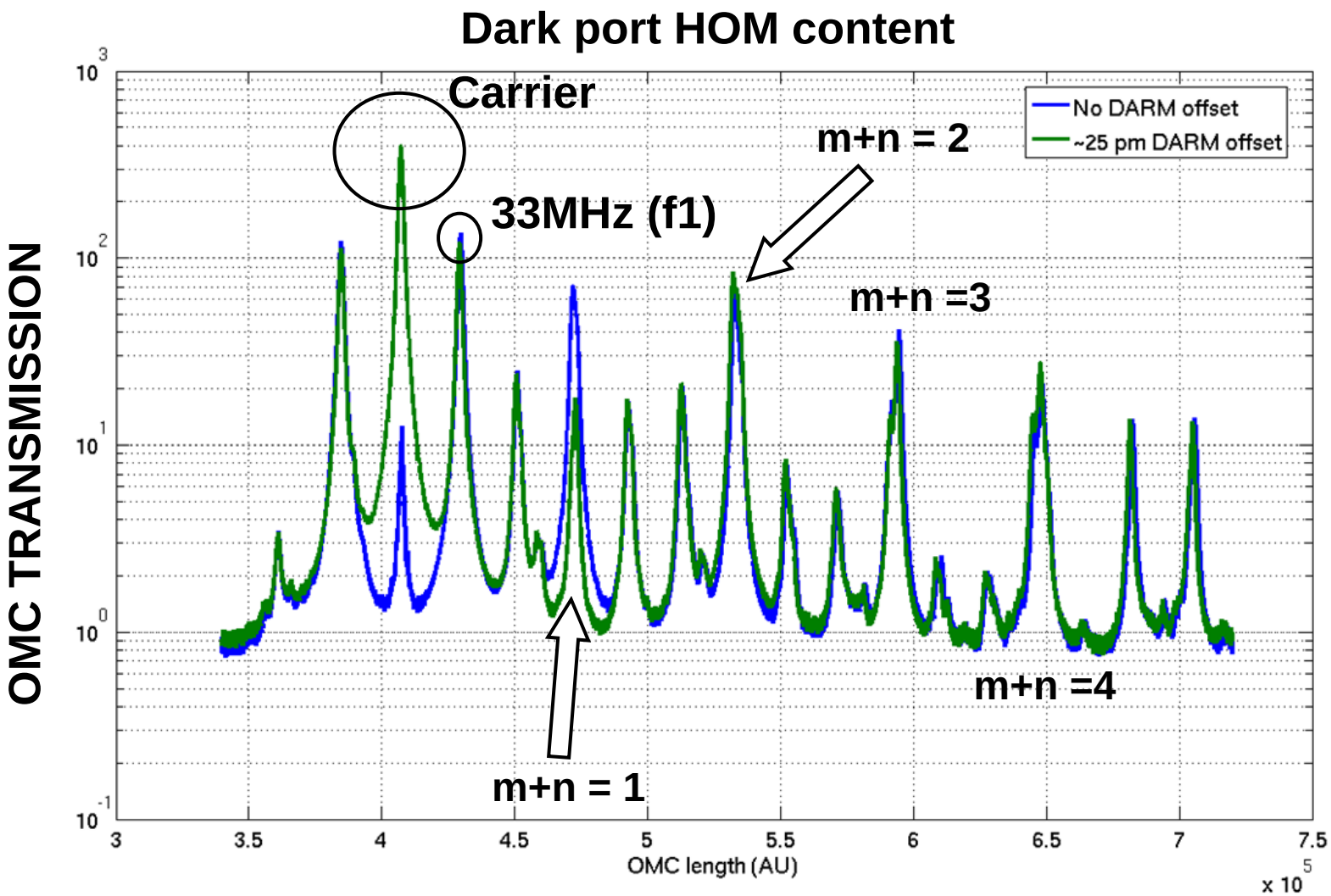
OMC: It cleans the modes

AS PORT Before OMC

OMC Transmitted



OMC Mode Scan (PRFPMI)



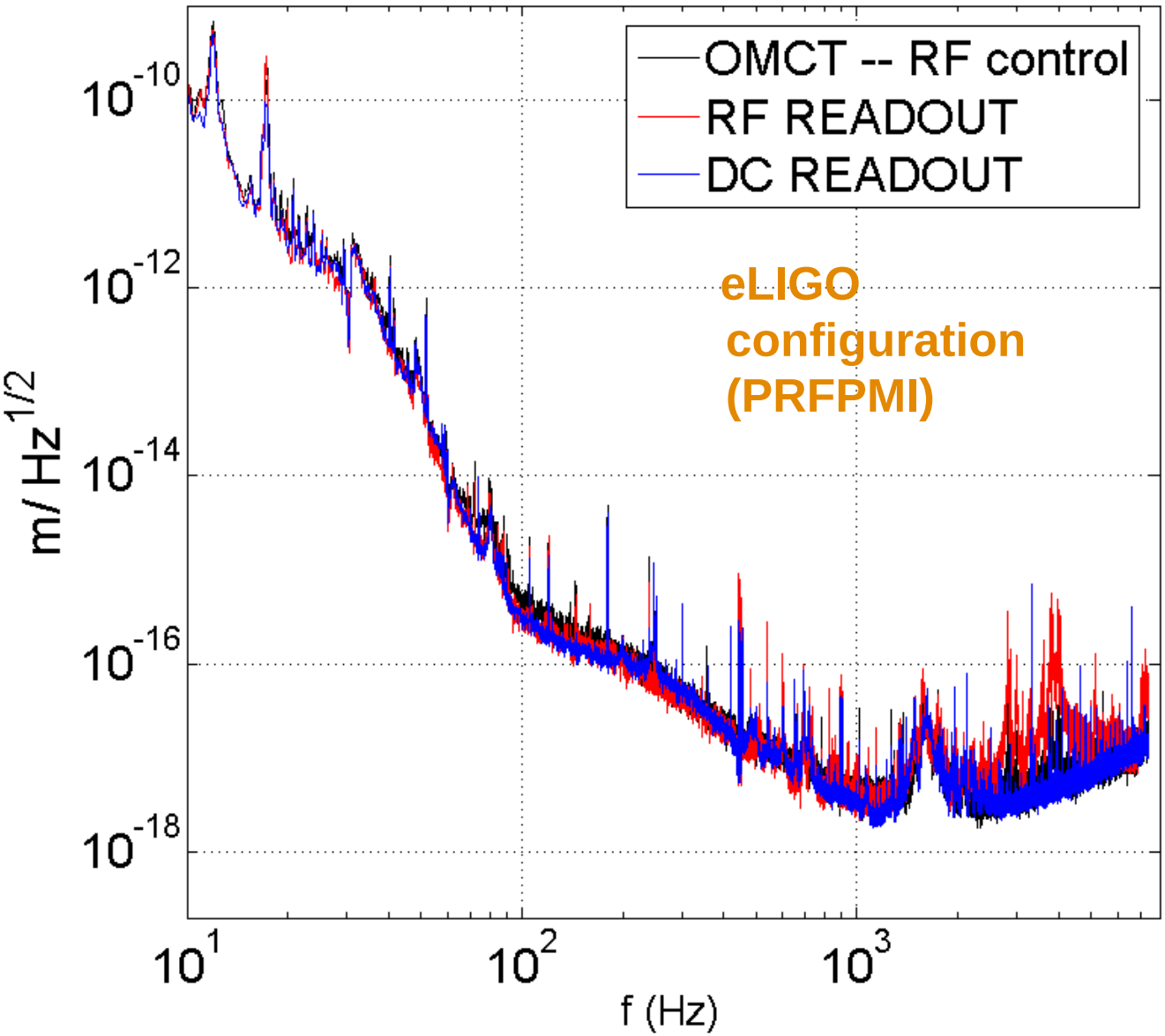
DC READOUT COMMISIONING

- most hardware installed, tested
  - » All PZTs, picos, PDs work as expected. Still QPDs to go.
- All software installed, tested
  - » **PCIX controls, interfaced successfully with current LIGO-like VME ISC control system. This result is important for eLIGO.**
- OMC Controls ***VERSION 1.0***
  - » All digital demodulation, without using an AWG
  - » OMC Length dither ***locked*** (dither freq 12kHz, UGF 100Hz)
    - – dither amplitude ~ 5 pm
  - » OMC Alignment Sensing & Control
    - – dither **locked** (two tip/tilts, 4 DOFs)
    - – dither freqs ~4 - 7 kHz
    - – servo bandwidth: 2@20Hz, 2@subHz
    - – dither amplitude ~ 5 urad (?)

RF vs DC: Displacement Noise

DARM offset ~35pm

Developed a new PRFPMI lock acquisition technique along the way.

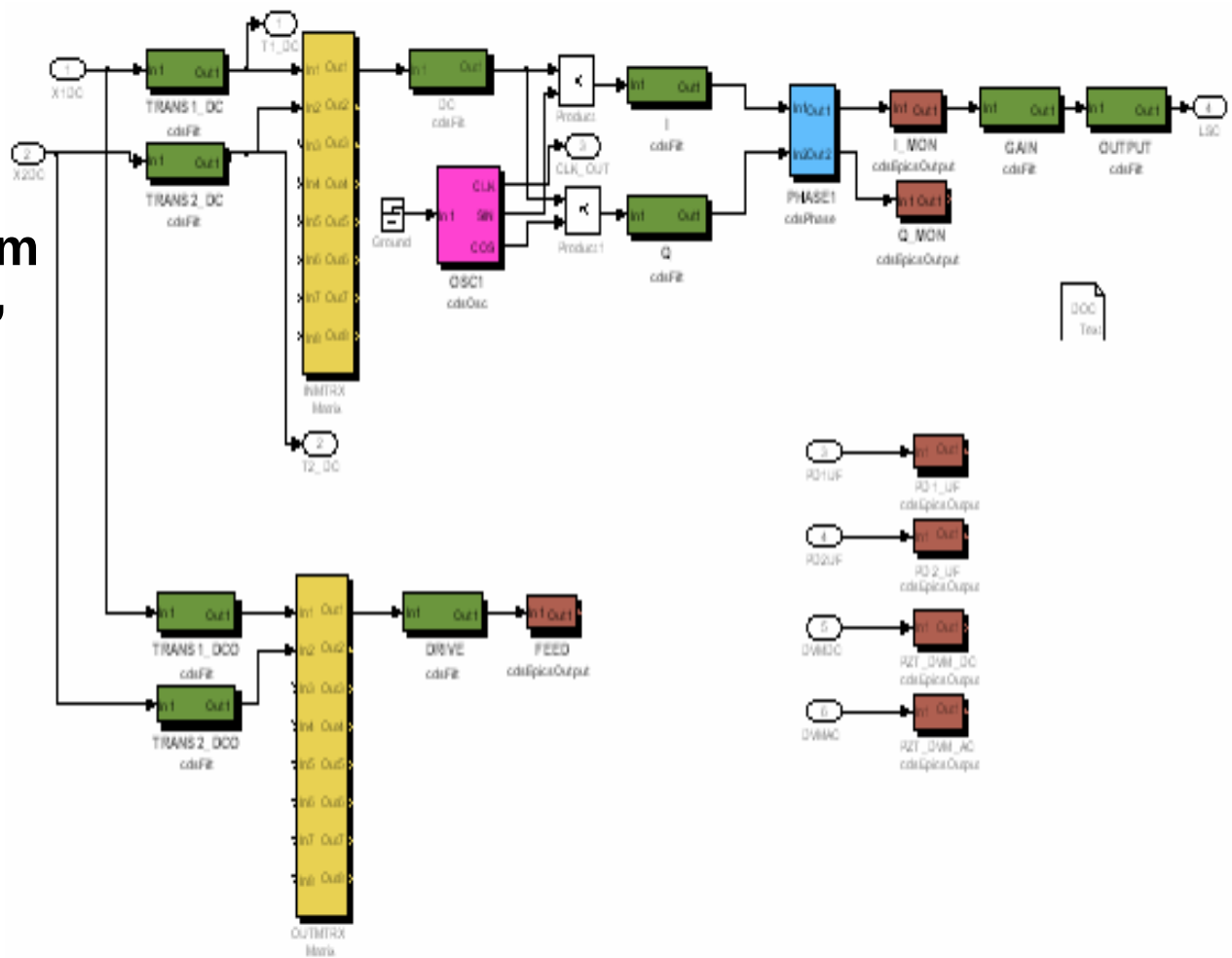


NEXT for DC Readout

- Optimization of auxilliary loops
  - » **NOISE-BASED** optimization of OMC controls
- A little bit of noise hunting
- Measure laser noise transfer functions, compare with models
  - » Frequency noise
  - » Intensity noise
  - » Oscillator phase noise
- Map out optimal DARM offset, compare with modeling.
- DC Readout with **SIGNAL RECYCLING**

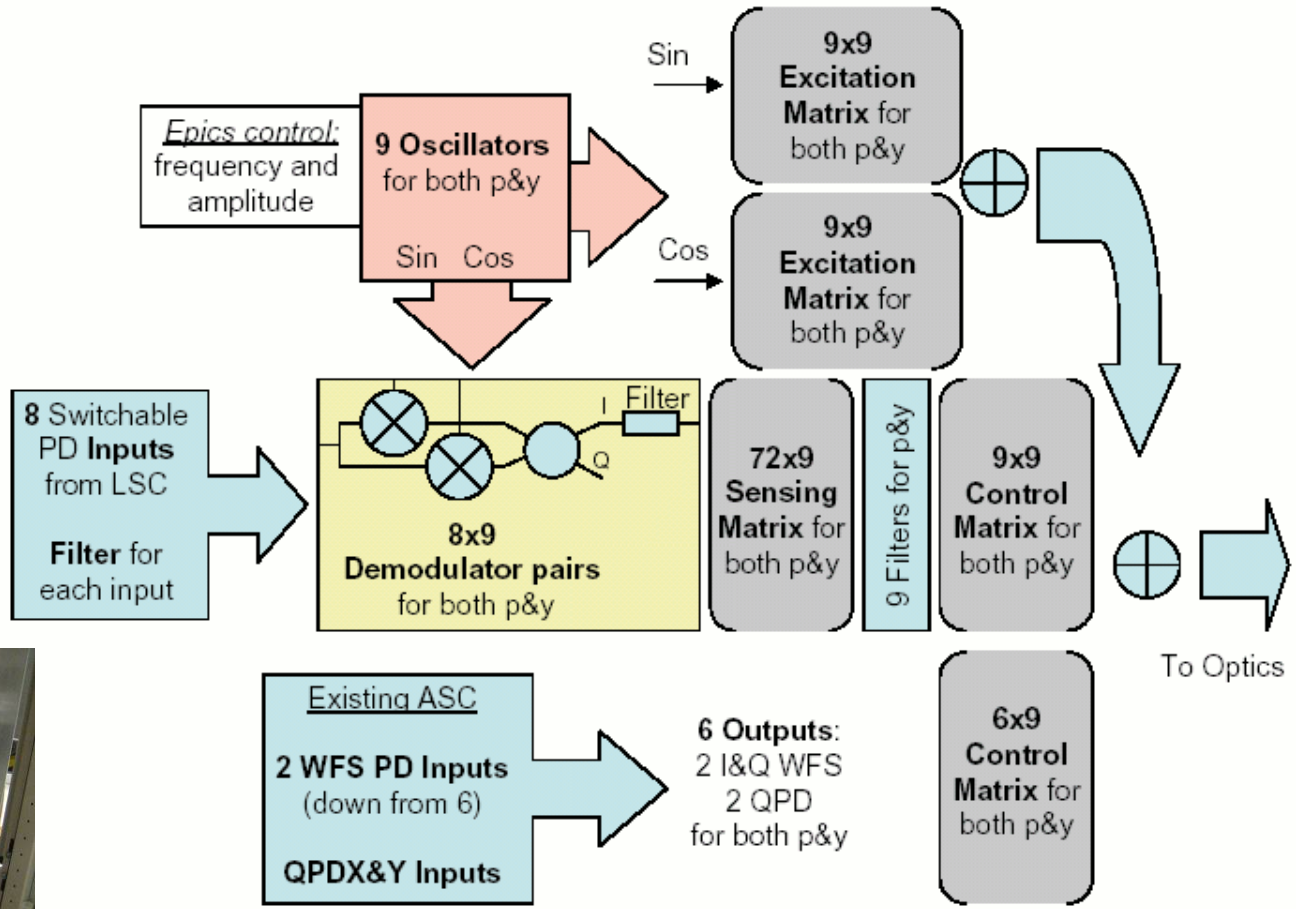
New Digital Controls Systems

- **BorkSpace front-end code generation system**
- **Just type “make” then build MEDM screens and you’re ready.**

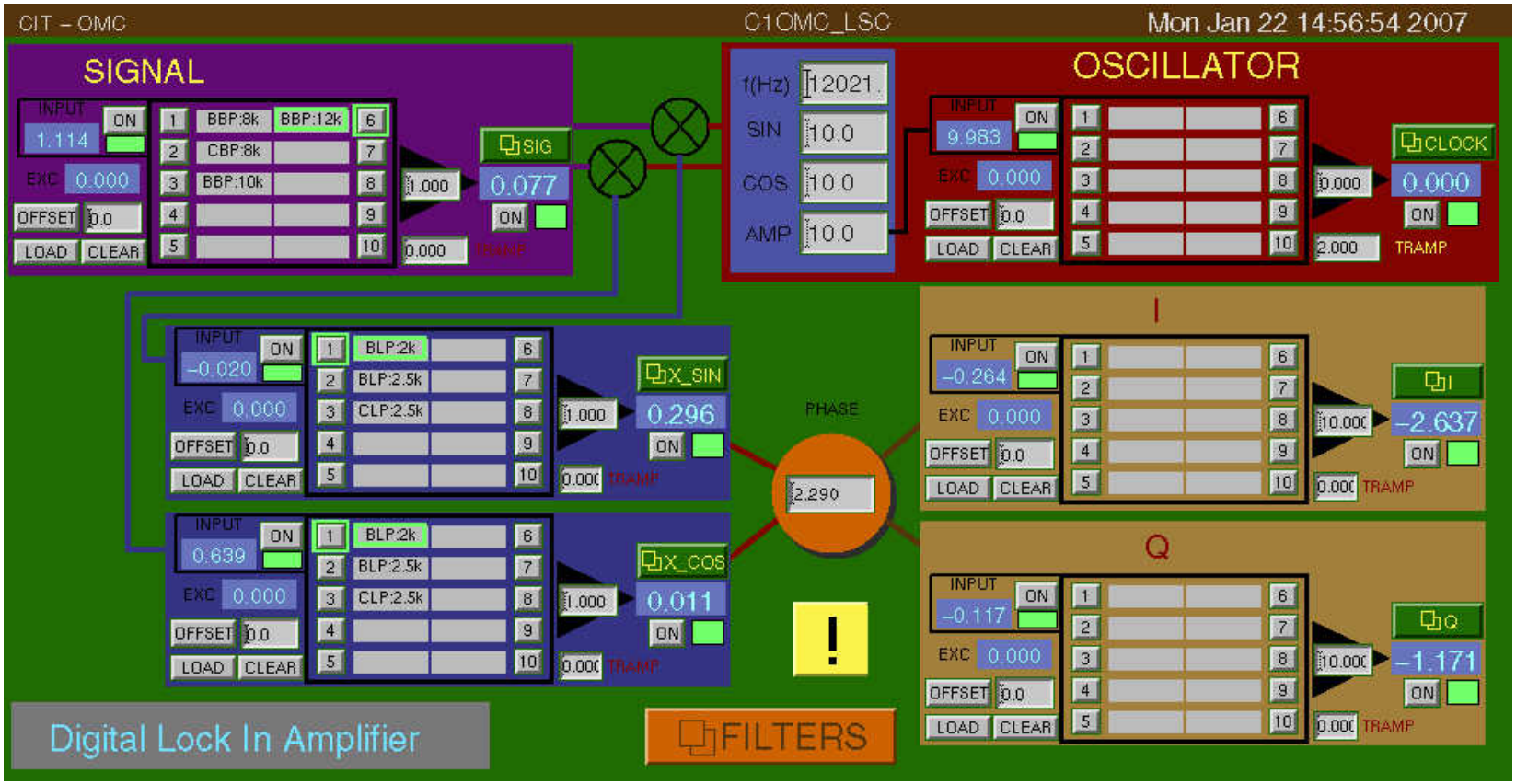


Alignment Sensing & Stabilization

- Dither each suspension in pitch & yaw, demod at various signal ports. No AWG.
- ULB alignment and spot centering.



Digital Lock-in



Summary & Future plans

- DC Readout in an eLIGO like configuration is in full swing. Quantitative measurements & comparisons with RF schemes coming (very) soon->Noise budget.
- DC Readout in an AdLIGO style IFO coming soon.
- Finish commissioning IFO dither alignment system.
- Possible integration of vacuum squeezing with OMC/DC Readout in the medium term.
- New AdLIGO – style CDS infrastructure working well, and meshing with current LIGO – style CDS infrastructure.
- We have ~100 ppm loss per test mass. Plan to do some tests to investigate/mitigate this in the near term.