Testing Advanced LIGO length sensing and control scheme at the Caltech 40m interferometer.

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Overview

- Caltech 40m is a prototype interferometer for Advanced LIGO
- Dual-Recycled Fabry-Perot Michelson Interferometer

Current Status

We locked DRFPMI with DC readout

Next plan

- Current 40m:
  Reconfigured to be as close as possible to the AdvLIGO control scheme circa 2001

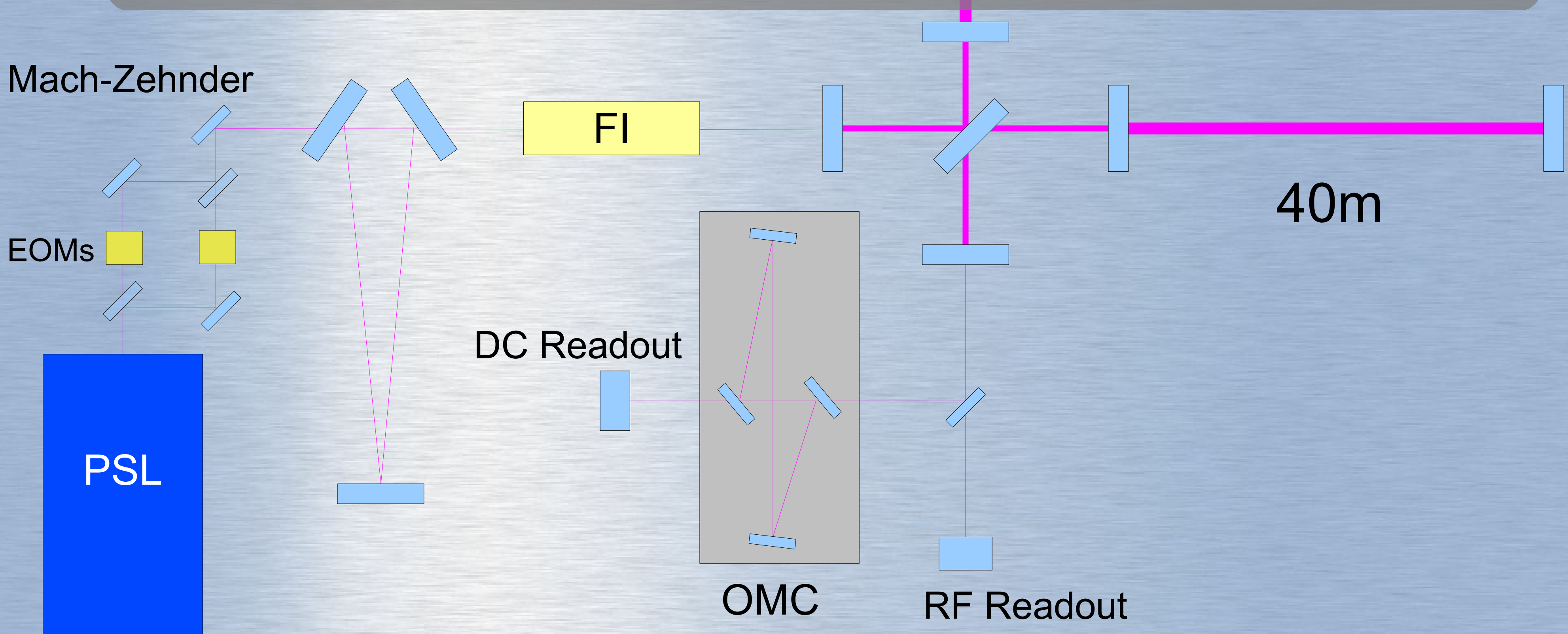
- Based on the lessons learned at the 40m and elsewhere, the AdvLIGO control scheme was substantially modified.

- We plan to modify the 40m to test this new control scheme.

- Other interesting stuff:
  Advanced Lock Acquisition Techniques, Adaptive Noise Canceling, etc

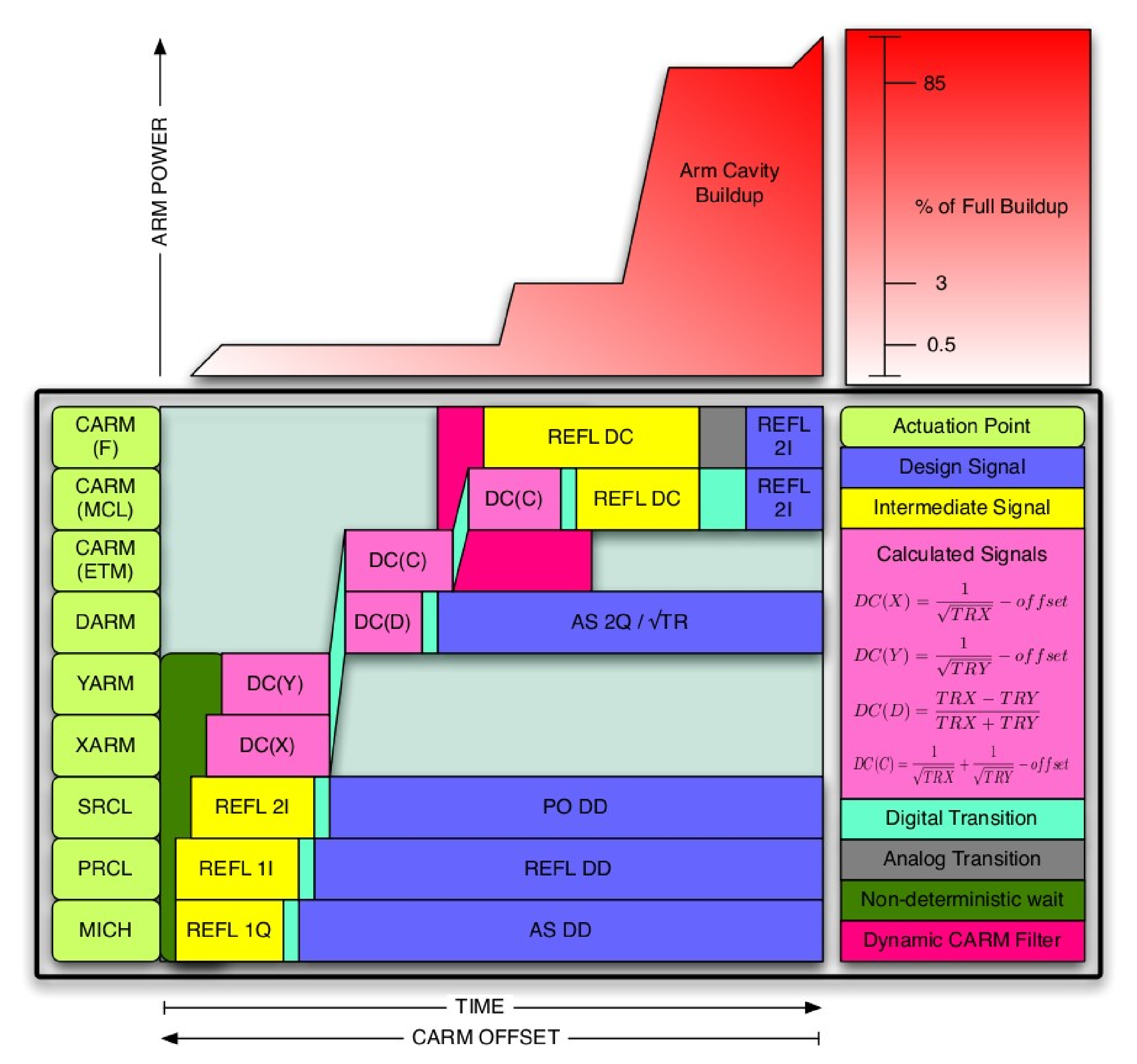
Caltech 40m Interferometer

- 40m is a fully equipped advanced detector prototype
- Initial LIGO Laser with frequency and intensity stabilization
- 11m Mode Cleaner (MC)
- All the core optics are suspended on single pendulums like initial LIGO
- Digital control system
- Output Mode Cleaner (OMC)



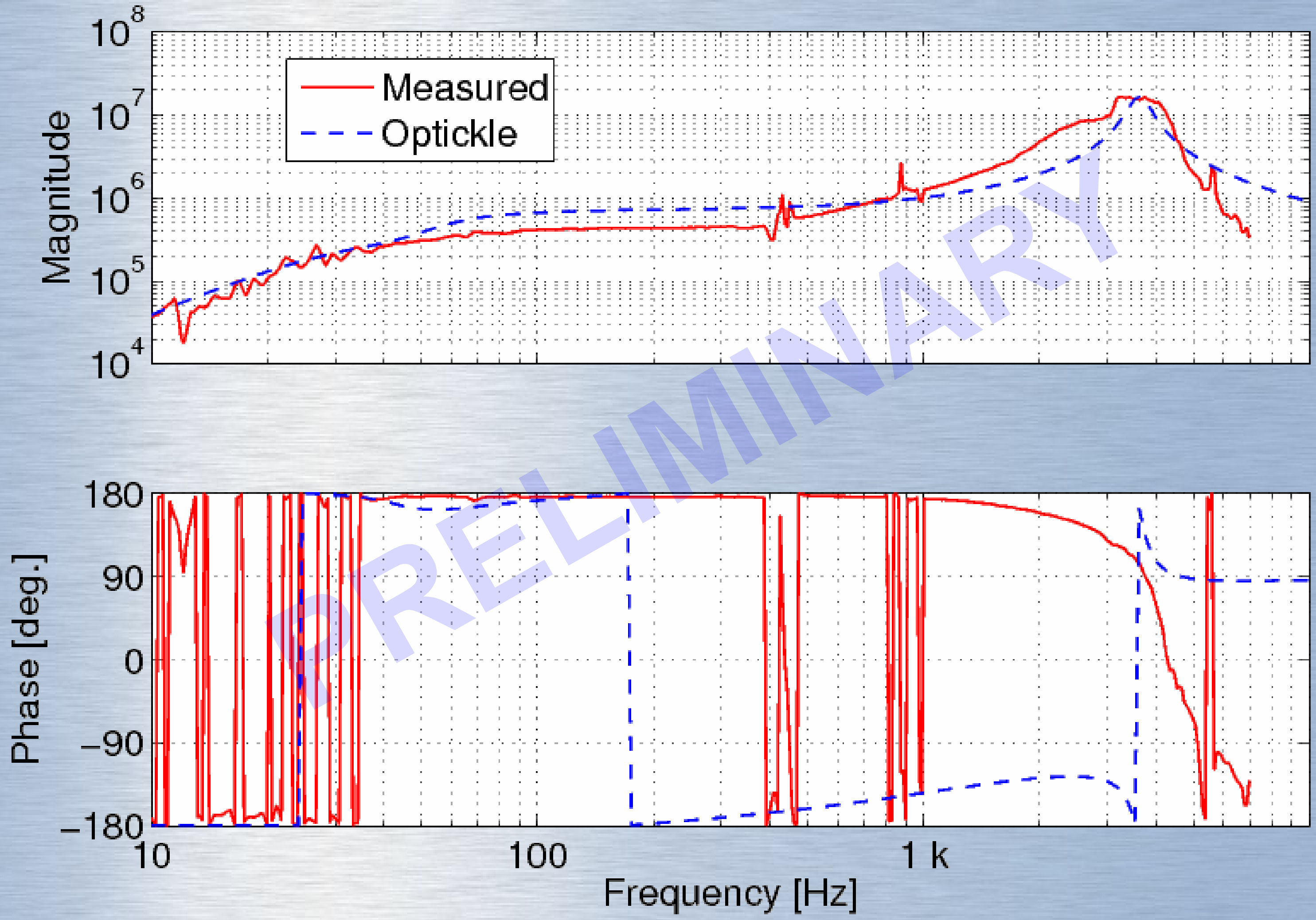
Lock Acquisition Work at the 40m

- Lock the arms with some offset
- Switch error signals and feedback points as the offset is reduced
- Final State: Detuned RSE with DC Readout



We locked the IFO !

- Detuned RSE DARM Response with DC Readout
- RSE resonance at 3.8kHz
- Locked the SRC on the anti-spring side (no optical spring peak)
- Not calibrated yet



Will investigate laser noise couplings of DC readout

AdvLIGO Sensing and Control Scheme

The AdvLIGO Length Sensing and Control (LSC) Design was modified since the current 40m was reconfigured.

Problems

- Modulation frequencies are too high (33MHz and 165MHz)
- Arm finesse is too high (1250)
  sensitive to loss, difficult to lock, coating thermal noise, etc
- Fixed detuning phase
- Mach-Zehnder is a source of headaches

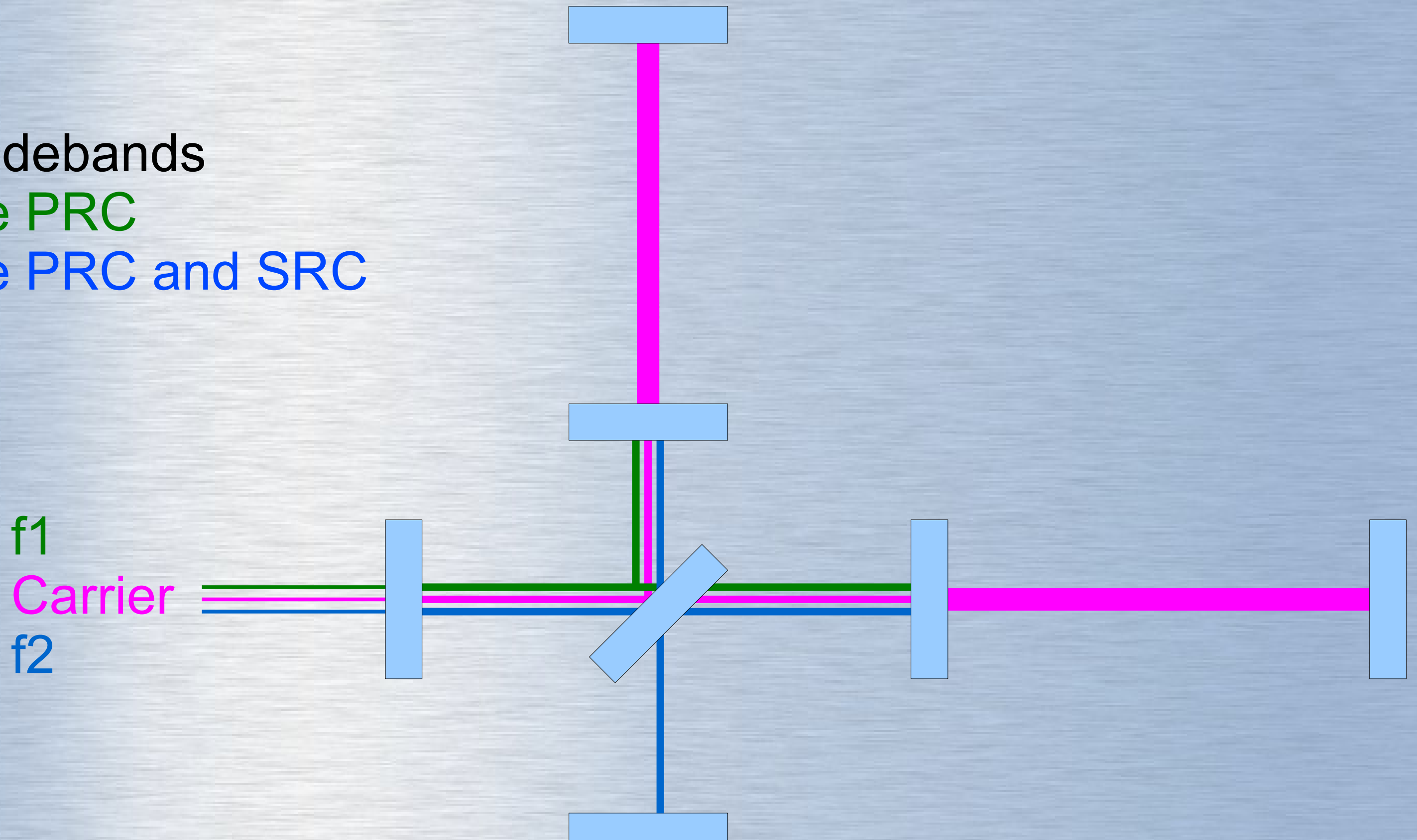
Solutions

- New LSC scheme → Lower modulation frequencies (9MHz & 45MHz)
- Lower absorption material → Reduced arm finesse (450)
- Moderate signal recycling gain → Continuously variable SRC detuning
- No double demodulation → No Mach-Zehnder

New LSC Scheme

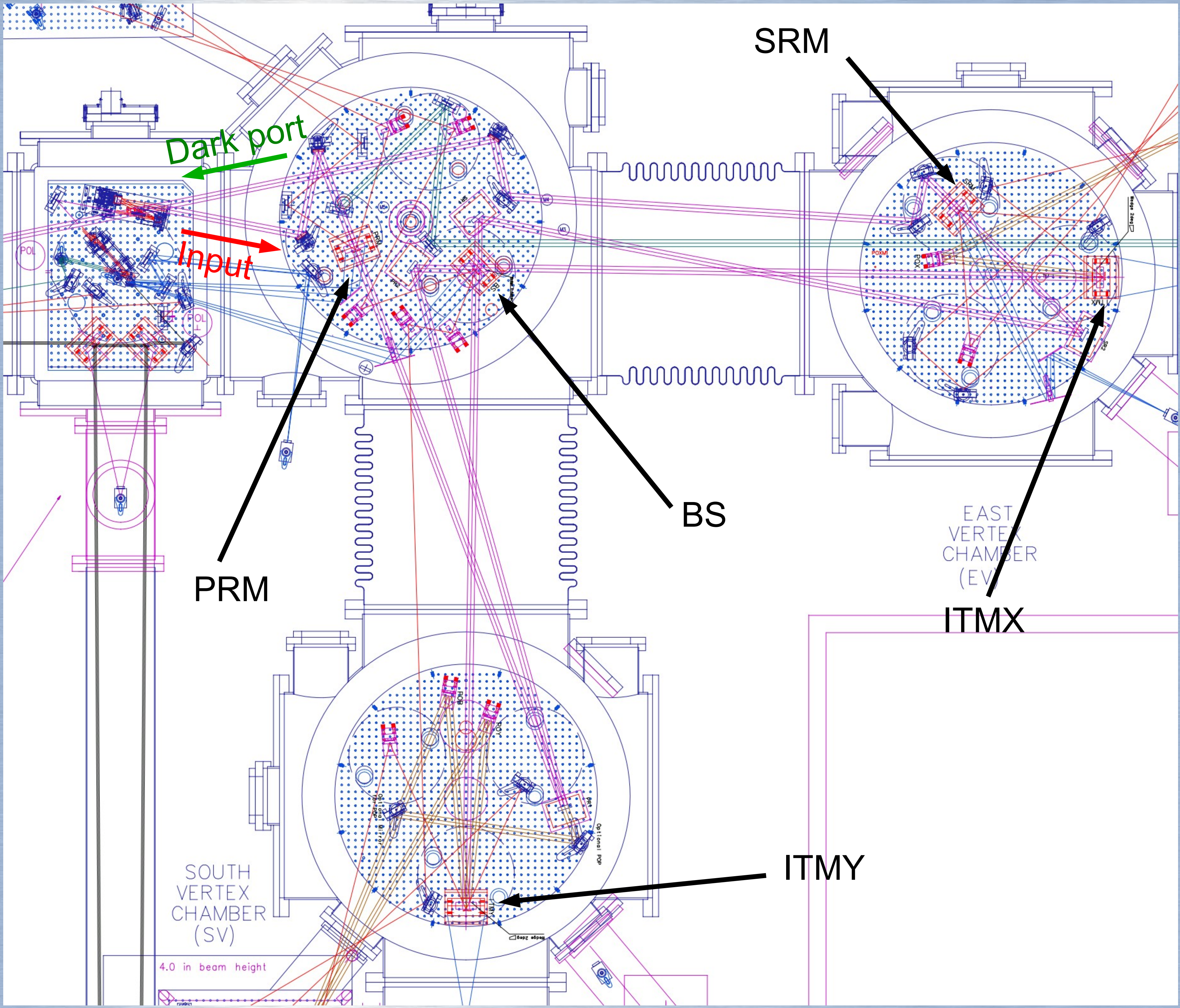
- Michelson asymmetry is small
- f2 makes to the SRM by critical coupling of the PRC and SRC
- Separation of f1 and f2 can be smaller
- Base line is a broadband RSE (zero detuning phase)
- Error signals: single demodulation signals
- Continuously variable detuning by SRC offset

Two sidebands
f1: see PRC
f2: see PRC and SRC



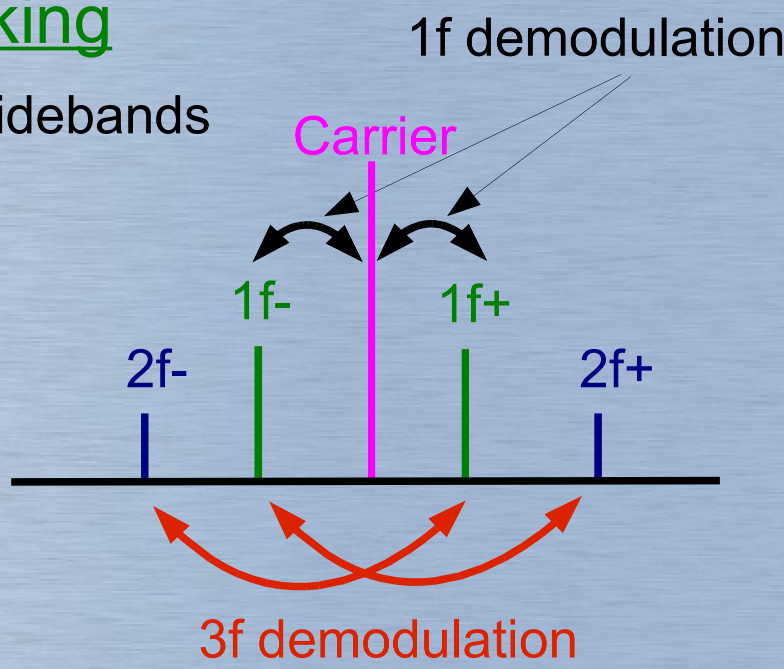
Upgrade Plans

- Lower Modulation Frequencies (11MHz&55MHz)
- No Mach-Zehnder
  - Double or Triple Resonance EOM
- Longer Recycling Cavities
  - Tip-Tilt stages for folding mirrors
- New Input Test Masses (ITMs)
  - Lighter (for larger radiation pressure effect)
  - Lower arm finesse (450)
  - Dichroic coating for green laser
- 3rd harmonics demodulation (3f) signals for lock acquisition
- New Digital Control System
- Adaptive Noise Canceling


SRM
Dark port
Input
BS
PRM
EAST
VERTEX
CHAMBER
(EV)
ITMX
SOUTH
VERTEX
CHAMBER
(SV)
4.0 in beam height
ITMY

3f signals for locking

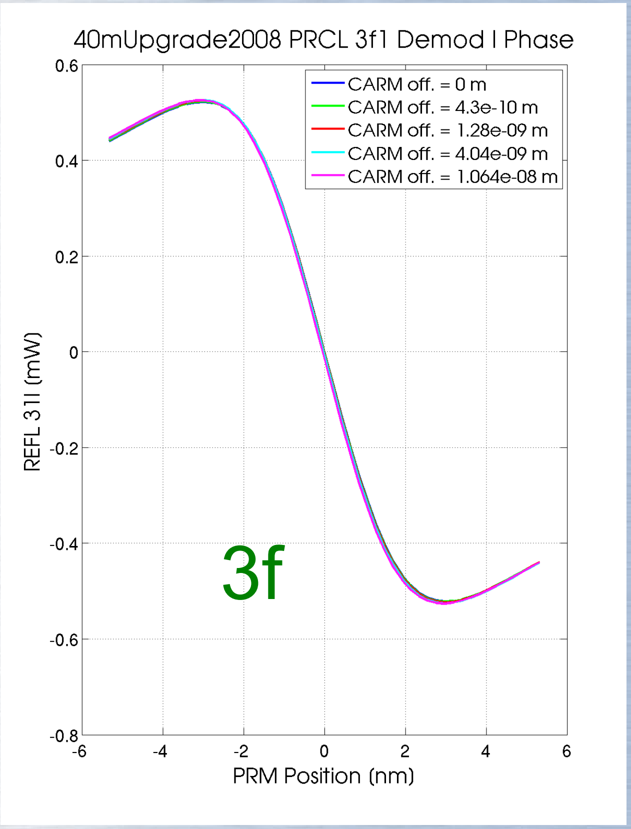
- Beat between the 2nd and 1st harmonics of the sidebands
- Not disturbed by the arm cavities

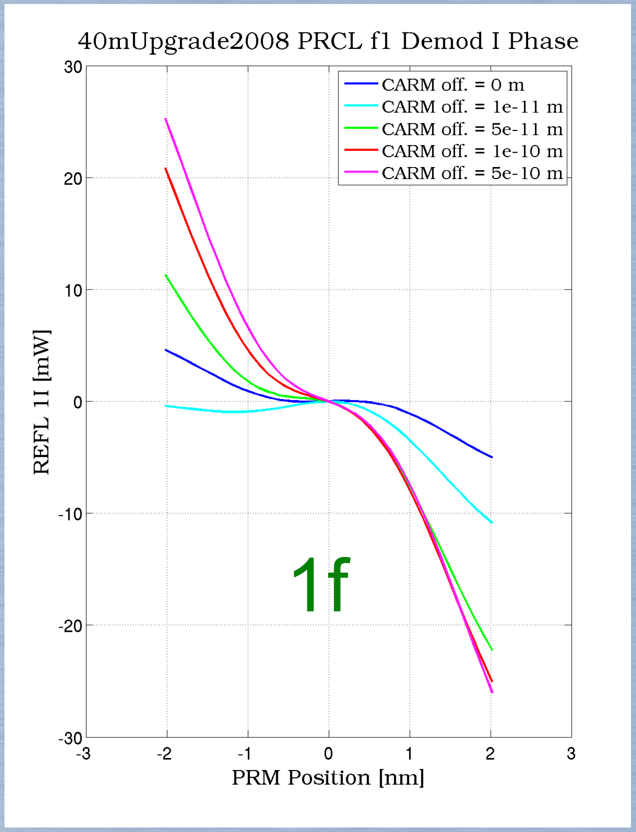


Resonant Conditions

	Recycling Cavity	Arm
Carrier	O	O
1f	O	X
2f	X	X

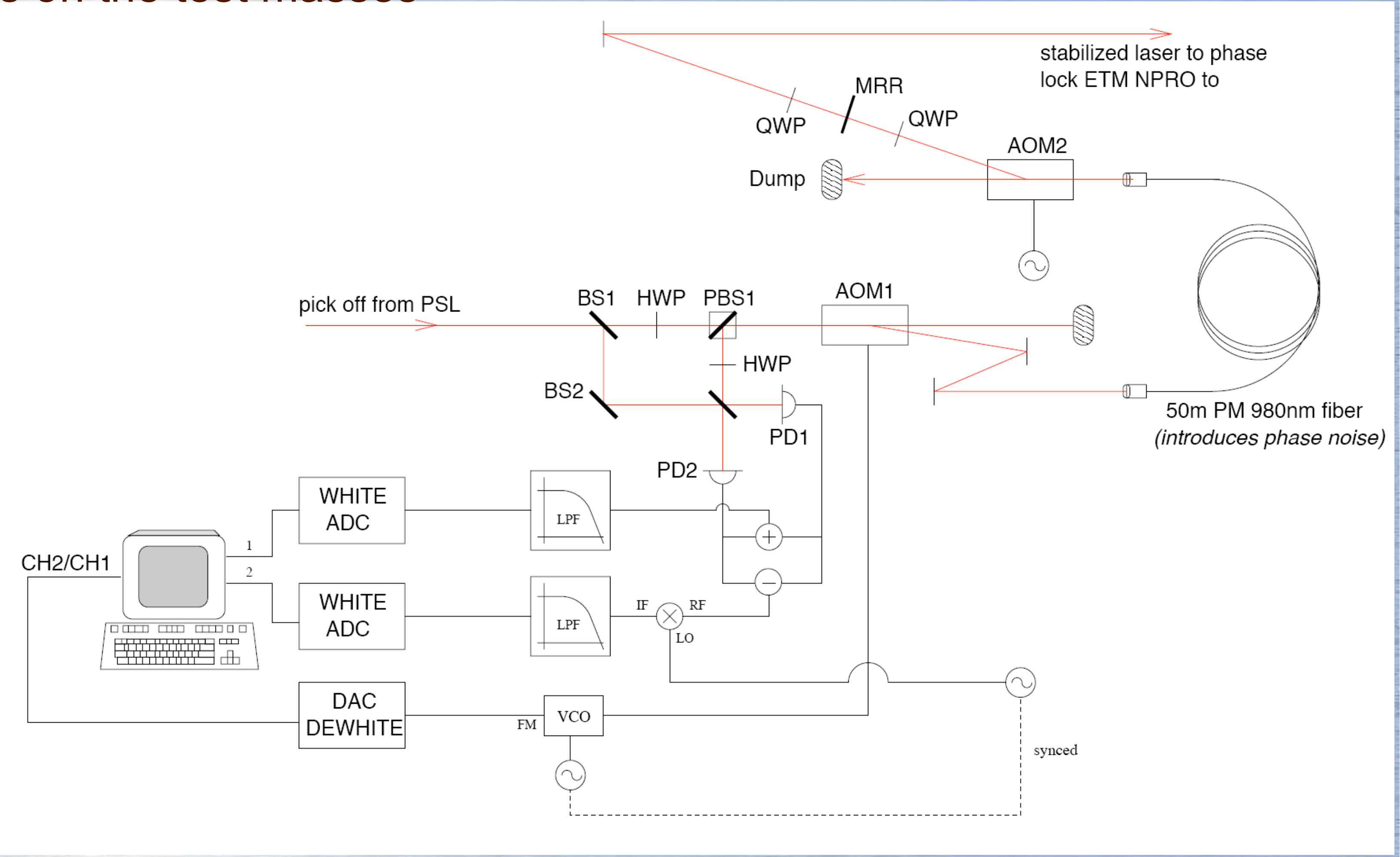
3f and 1f PRCL signal
as the CARM offset changed





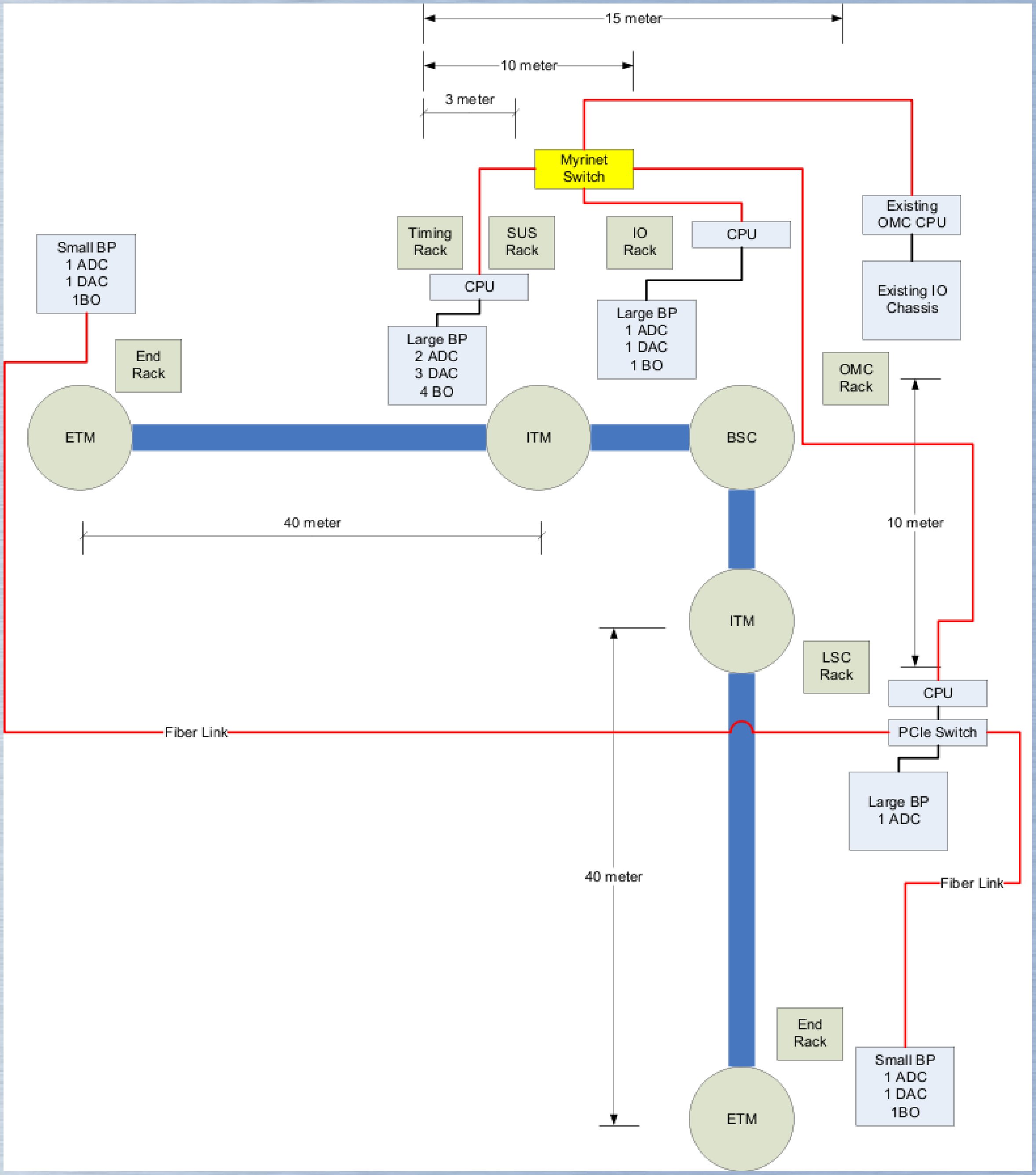
Green Laser Injection for Arm Pre-Lock

- Pre-lock the arm cavities with auxiliary laser injected from the ends.
- Prevent accidental resonances of sidebands in the arms during the lock acquisition.
- Gently bring the arms to the resonance in a controlled manner.
- Picked-off beams from the main laser are sent to the ends through optical fibers.
- Fiber noise is actively canceled
- Frequency-doubled green lasers phase-locked to the main laser are used for the pre-lock.
- Dichroic coatings on the test masses



New Digital System

- Advanced LIGO style digital system (already used for the OMC)
  - Simulink based realtime code generator
  - More computational power (multi core machines)
  - Flexible: complicated state transitions during the lock acquisition
- Deploy in a full interferometer as full system test for AdvLIGO

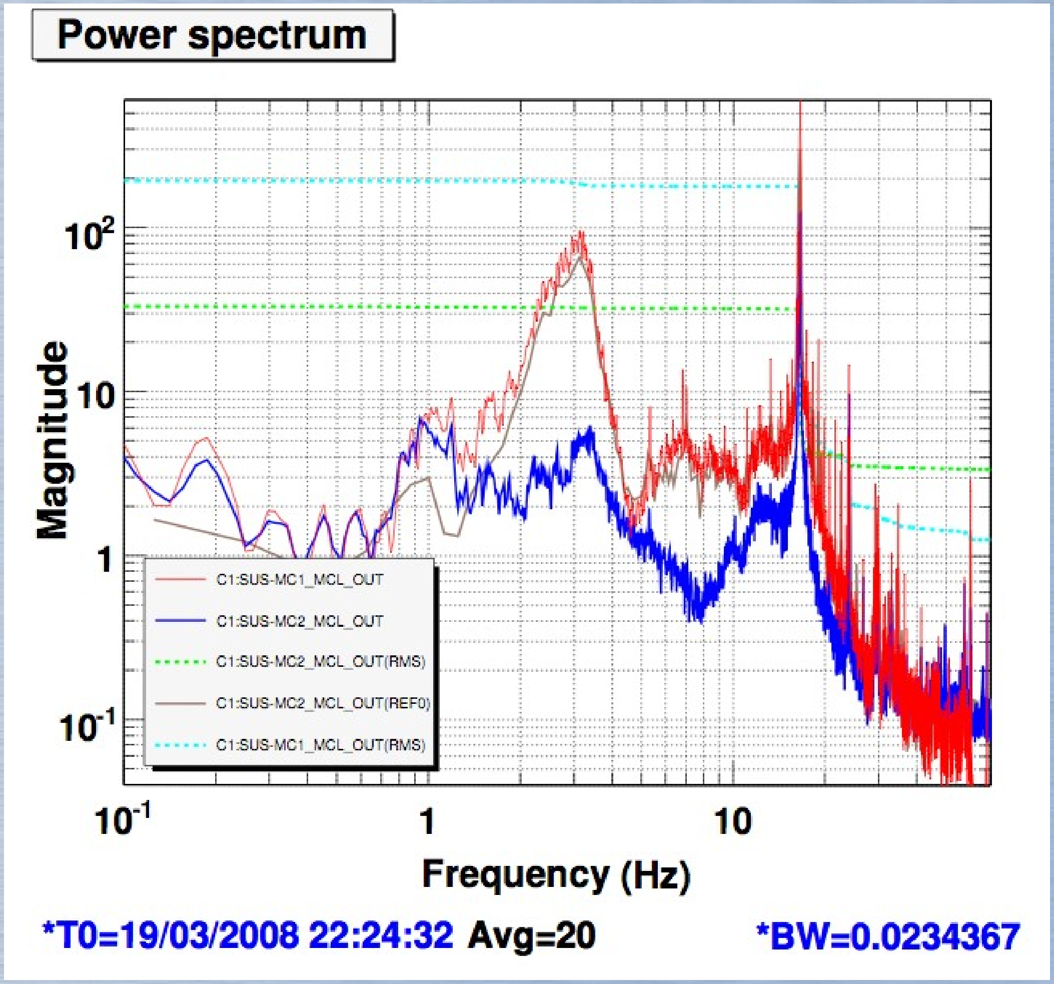


Adaptive Noise Canceling

Using environmental sensors, subtract noise from interferometer signals

- Sensors: seismometers, accelerometers microphones, magnetometers, whatever
- Subtract or feed-forward those signals through optimal Wiener filtering.
- Changing environment: Adaptive filtering
- Cancel noises not reduced by the suspension: Gravity gradient, magnetic field, etc
- Remove large peaks (sources of up-conversion noises)

Caltech 40m MC noise subtraction



Sensors:
Accelerometers and seismometers

MC Length Feedback Signal
Before filtering: Red
After filtering: Blue

Large peaks are well suppressed

Summary

Current Status

- Caltech 40m interferometer: Fully equipped advanced-detector prototype
- Successfully locked in the Detuned RSE configuration with DC readout
- Will investigate laser noise couplings to the DC readout

Future Plans

- Advanced LIGO LSC scheme has to be tested with a prototype
- A number of upgrades are planned at the 40m
  - New modulation frequencies
  - Longer recycling cavities
  - New ITMs
  - New digital system
- Advanced lock acquisition schemes
  3f demodulation, Green laser pre-lock of the arms
- Adaptive noise canceling