

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
- LIGO -

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LIGO SCIENTIFIC COLLABORATION

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<b>aLIGO Output Mode Cleaner: Overview of the realtime model and screens</b>		
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## 1 Objective and scope

The Advanced LIGO Output Mode Cleaner (OMC) is a suspended glass optical cavity for filtering radio-frequency optical sidebands and higher-order modes in the output beam of the interferometer. The cavity optics, peripheral optics, suspension interface, diodes for signal readout, and interface for electrical connections are built on a single fused silica glass breadboard. When the main interferometer is in operation, the OMC is supposed to be resonant only to the fundamental mode of the carrier light via length feedback control of the OMC PZTs, and the incident beam alignment is optimized via angle feedback control of the OMC Tiptilt mirrors and the OMC suspension.

The purpose of this document is to provide a brief description of the control system and the user interface in terms of the output mode cleaner control. The structure and functions of the realtime code (i.e. RCG codes) are described in Section 2, and the control screens (i.e. MEDM screens) are described in Section 3.

## 2 RCG: Realtime code implementation

The realtime code for the OMC is running on `x1omc` host, where “`x`” represents the site symbol. The functions implemented in the OMC model are listed below:

- Dithering of the OMC length and alignment (i.e. mechanical modulation)
- Receiving signals from the OMC breadboard photodiodes
- Demodulation of the transmitted light signal at the dithering frequencies
- Processing of the DC photodetector readout for the gravitational wave signal, or for other purposes.
- Blending of the alignment control signals
- Signal processing for servo control

The structure and the distribution of the functions in the model are described in the following sections.

### 2.1 OMC model root

The root of the OMC model (Figure 1) has the blocks in three categories:

**Model input:** It is located at the left most part of the screen shot. Local signals are obtained from the ADCs. Signals from the quadrant PDs are obtained from PCIe IPC (Inter Process Communication) connections.

**OMC block:** It is located at the center part of the screen shot. Most of the signals are fed to this OMC block. Most of the outputs from this block are sent to the DAC for the

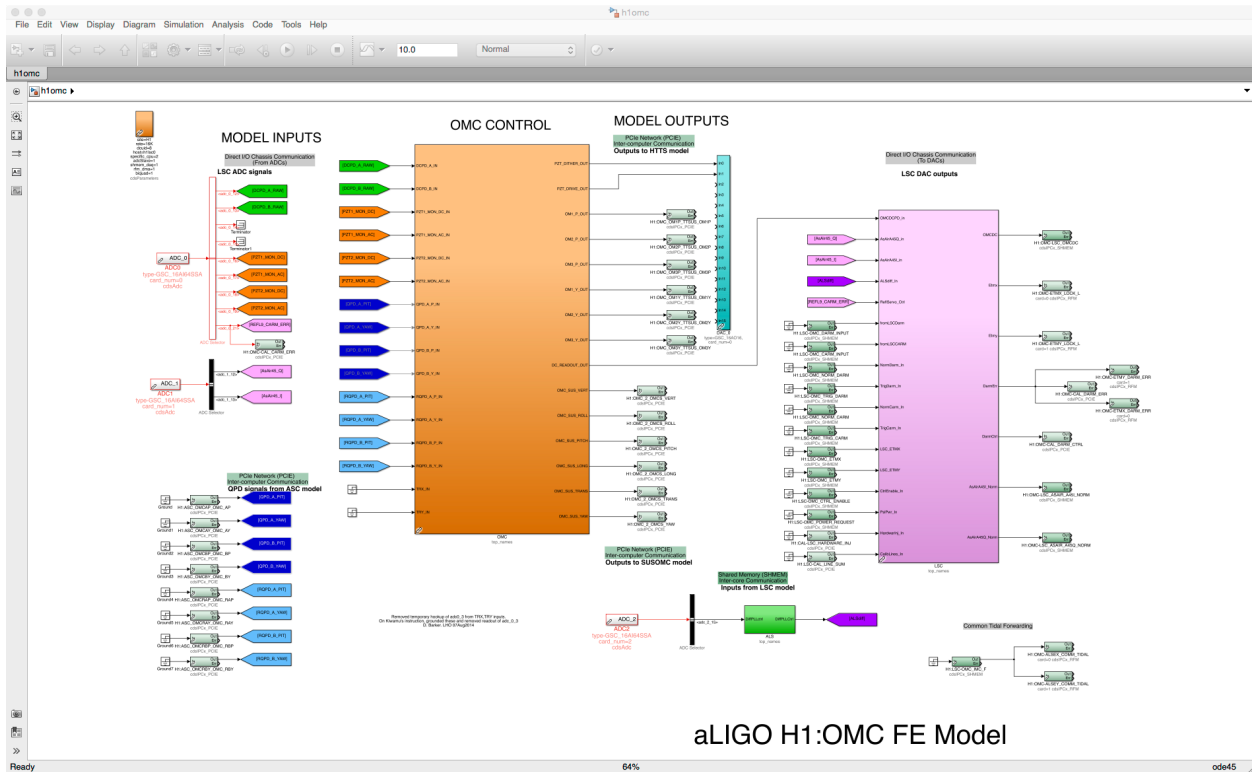


Figure 1: Root of the OMC model

OMC PZT control, or suspensions (OMC TTs and OMCS) for alignment control via IPC. The details of this block are described in Section 2.2.

**LSC and ALS blocks:** It is located at the right most part of the screen shot. LSC and ALS model were migrated from the LSC model to reduce the IOC load on the LSC host and the signal propagation delay of the DARM signal path.

## 2.2 OMC block

In practice, all the functions for the OMC are implemented in this block (Figure 2). There are six blocks:

**DCPD conditioning:** Signal conditioning for the DCPD signals are done in this block. The details are described in Section 2.2.1.

**Monitors:** This block provides calibration filters for the PZT DC/AC voltage monitors.

**DC Readout linearization/normalization:** Linearization / normalization functions are provided in this block. The details are described in Section 2.2.2.

**OMC Length sensing and control:** This block provides the functions for lockin detection and servo control of the OMC cavity length. The details are described in Section 2.2.3.

**OMC Alignment sensing and control:** This block provides the functions for alignment sensing and control of the OMC cavity. The details are described in Section 2.2.4.

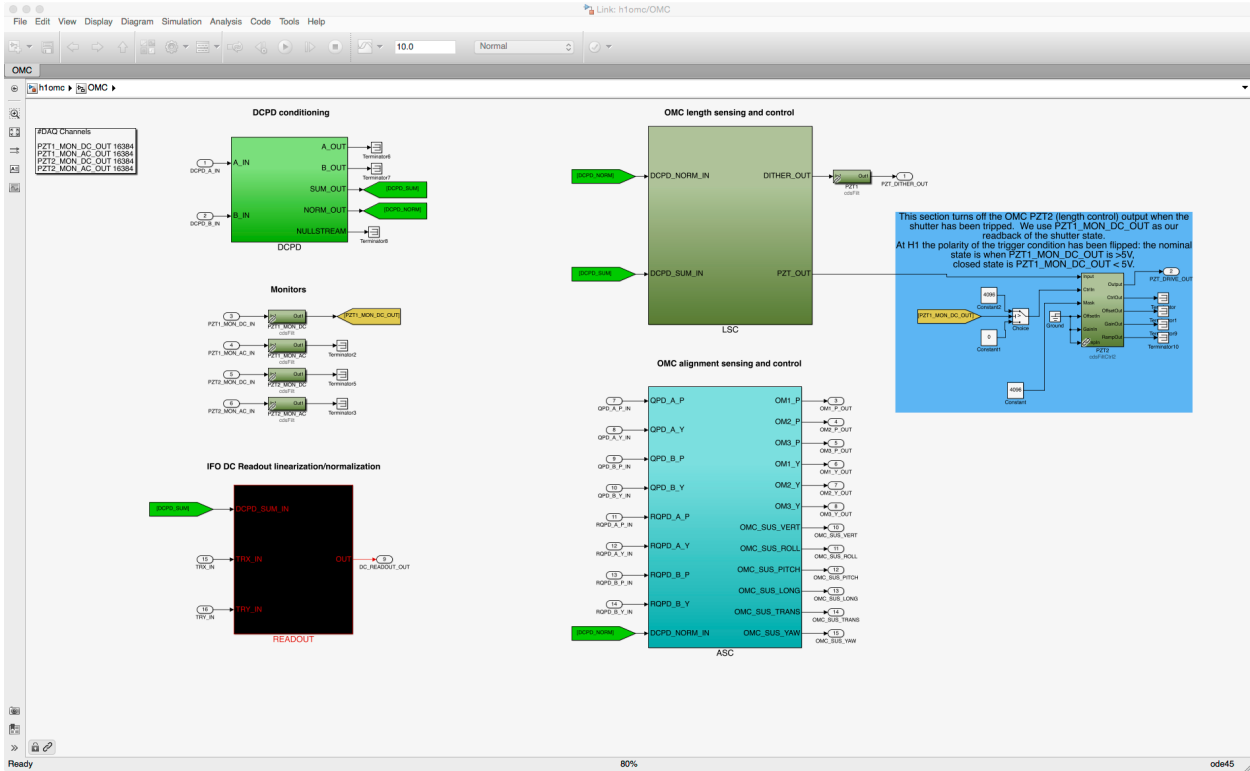


Figure 2: OMC block

**OMC shutter:** The right most part of the model provides disabling function for PZT2. When the analog fast PZT shutter is tripped, PZT1\_MON\_DC\_OUT goes less than 5V (4096 count). In this state, the input voltage of PZT2 is blocked and disables further actuation.

### 2.2.1 OMC/DCPD subblock

OMC/DCPD subblock (Figure 3) provides signal conditioning for the DCPD signals.

The input signals goes into two identical signal processing blocks. The input filter is used for calibration and anti-whitening. The output from the input filter is used to calculate the RMS value of the signal for monitor purposes. The calibrated filter outputs are balanced and separated into common (SUM) and differential (NULL) components. The SUM output is further normalized by the low frequency component of itself to calculate the relative intensity noise that is indicated as NORM\_OUT.

### 2.2.2 OMC/READOUT subblock

OMC/READOUT subblock (Figure 4) provides the linearization and normalization function of the DCPD SUM signal. This linearization/normalization algorithm is based on the description in [1]. There is also a switch (named “BYPASS”) to bypass all of these operational blocks.

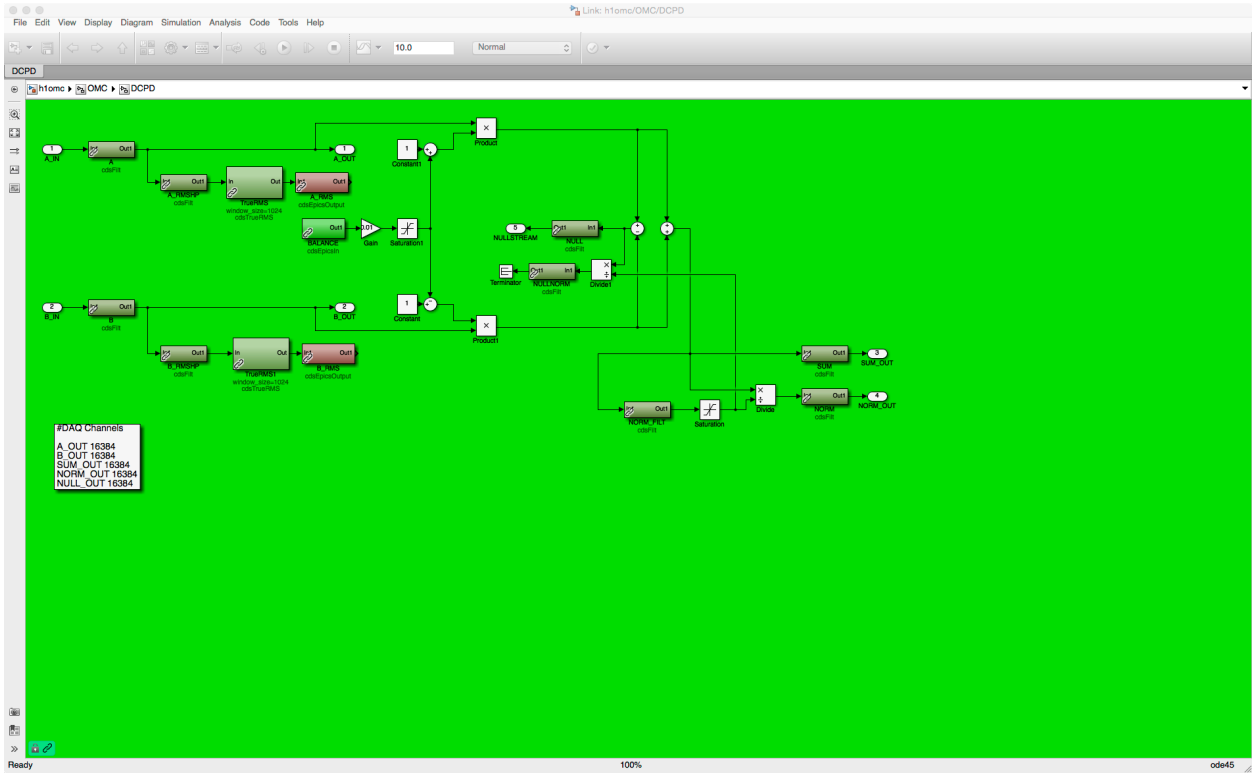


Figure 3: OMC DCPD subblock

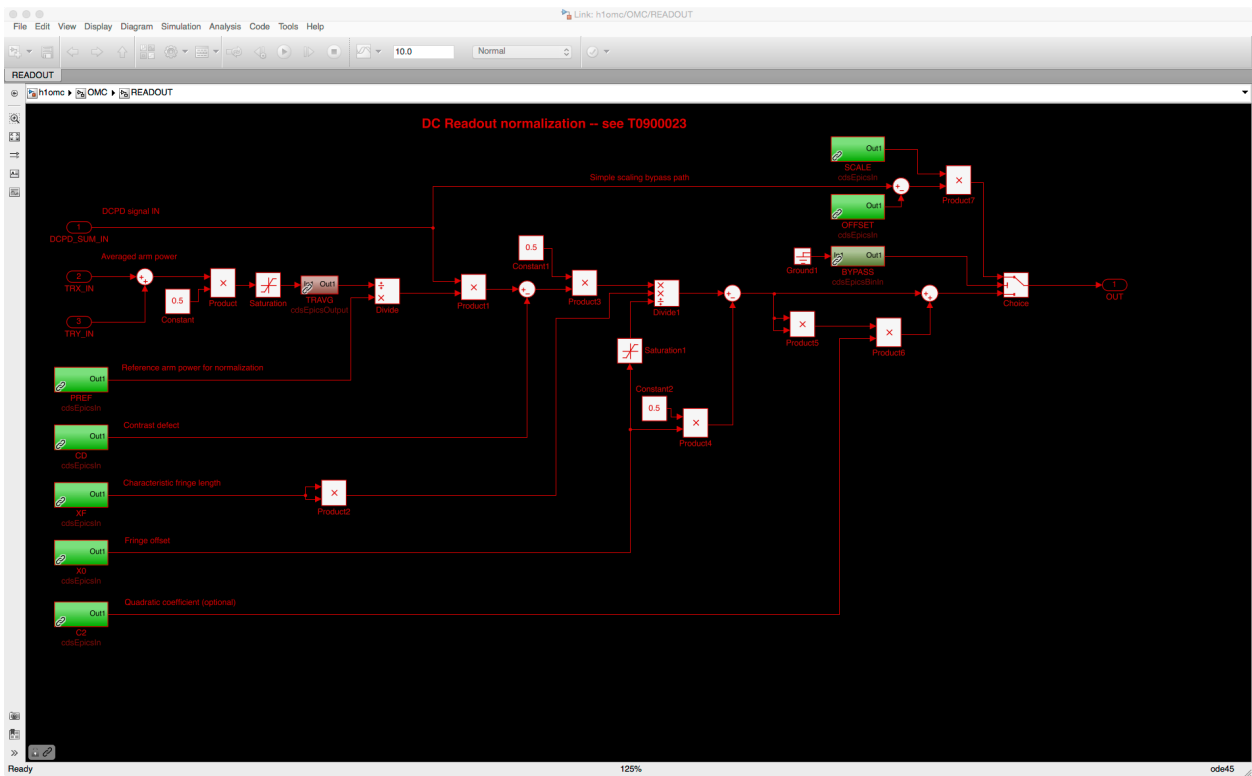


Figure 4: OMC READOUT subblock

### 2.2.3 OMC/LSC subblock

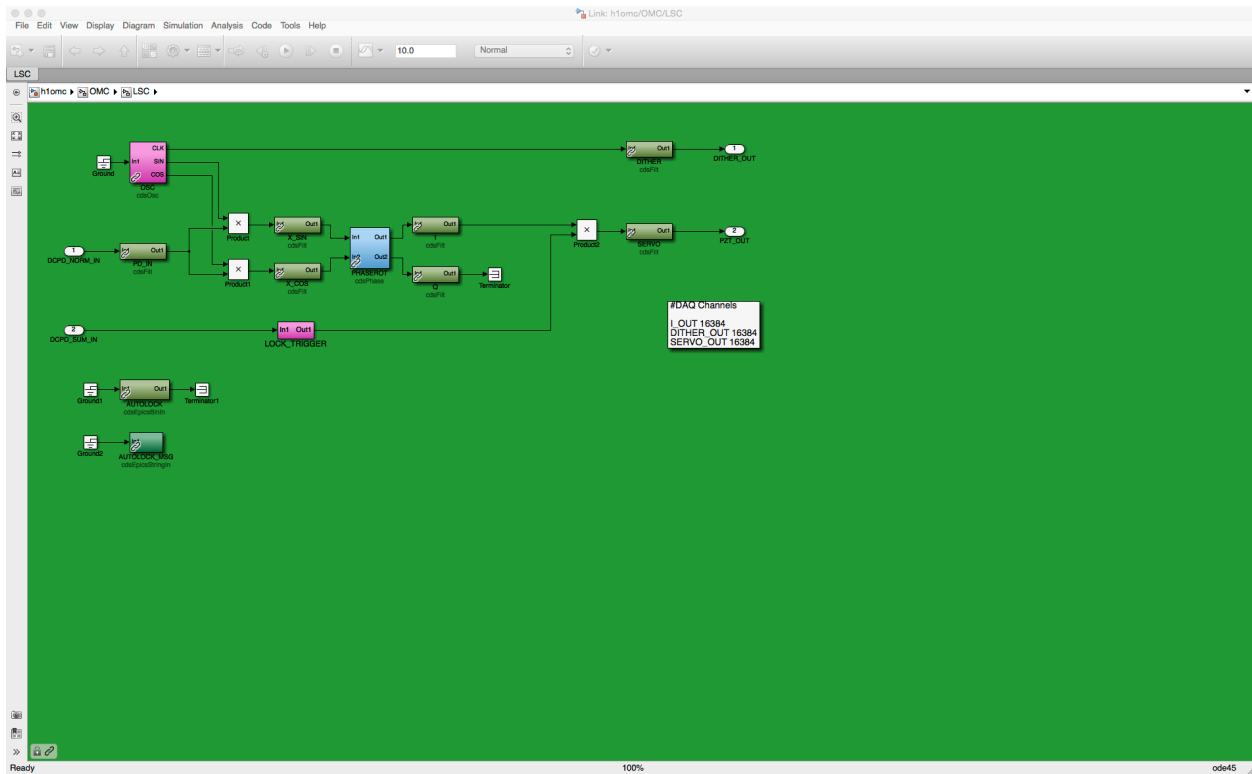


Figure 5: OMC LSC subblock

OMC/LSC subblock (Figure 5) provides lockin detection and servo control for OMC length control.

In this subblock, there is a local oscillator that is used to modulate one of the PZTs used for length dithering. The normalized output from the DCPD subblock is demodulated by the orthogonal oscillator signals for sin and cos quadratures in order to perform lockin detection. We are able to select arbitrary lockin phase by the phase rotator. Only the I-phase output is used for control and the Q phase signal is discarded. The I-phase signal goes into the servo filter module that is at the right most part of the screen shot, indicated as SERVO. The unnormalized DCPD.SUM signal is used for triggering the servo input signal.

### 2.2.4 OMC/ASC subblock

OMC/ASC subblock (Figure 6) provides the functions for OMC alignment control.

Similarly to the OMC/LSC subblock, this subblock has local oscillators. The OMC ASC uses not one but four oscillators (indicated in pink), for the control of four degrees of freedom. These oscillator signals are fed to OM1, OM2, and OM3 tip-tilt mirrors via an output matrix (DITHERMAT at the bottom).

The normalized output from the DCPD subblock is demodulated by 4 pairs of orthogonal oscillator signals (P1OSC, P2OSC, Y1OSC, and Y2OSC) for sin and cos quadratures at four different dither frequencies. Each pair has phase rotator for demodulation phase selection

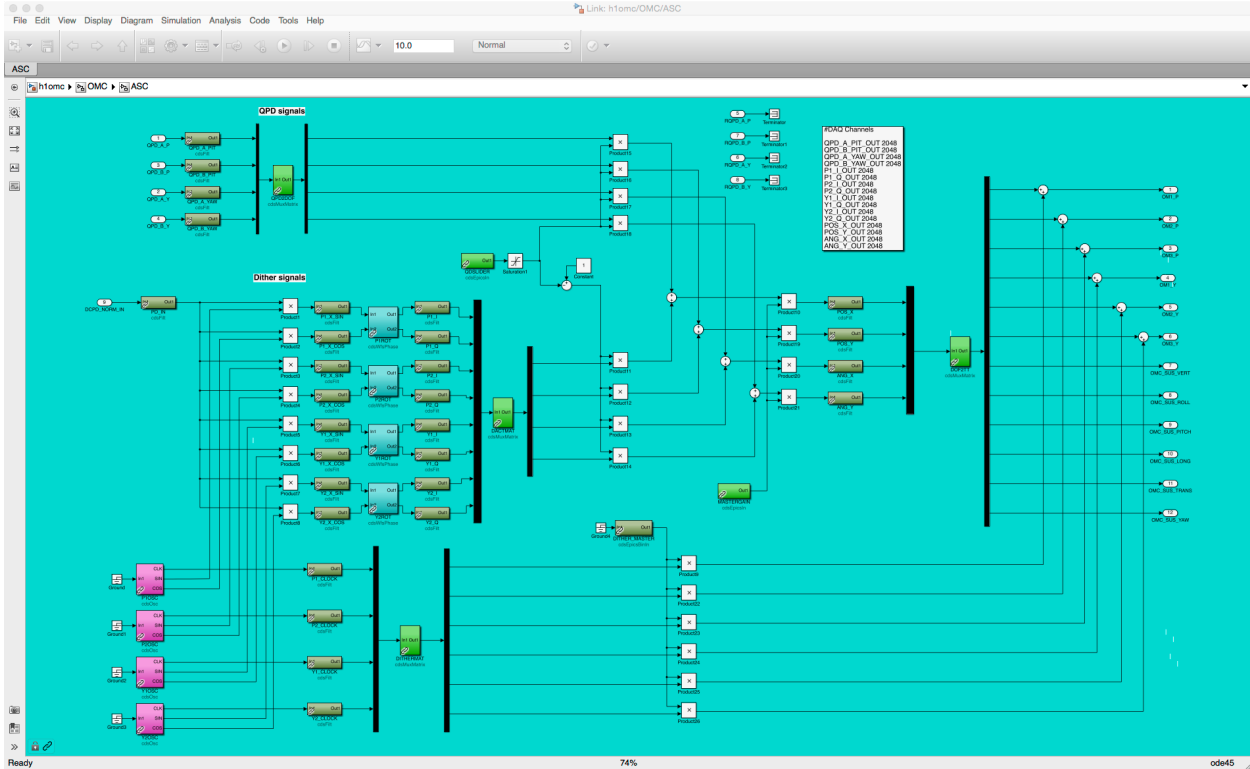


Figure 6: OMC ASC

(P1ROT, P2ROT, Y1ROT, and Y2ROT). The eight outputs from the demodulators are fed to an input matrix (DACTMAT).

In fact we have two kinds of alignment error signals. One is the DC output from the OMC QPDs (at the top of the screen shot). The other is the dither alignment signal described above. There is a signal blender (QDSLIDER) to continuously ramp between the QPD and dither signals.

The four filter modules (POS\_X, POS\_Y, ANG\_X, and ANG\_Y) implement the servo control for the four DOFs. The servo output can control the OMC tip-tilts (OM1, OM2, and OM3) and 6 DOFs of the OMCS suspensions (VERT, ROLL, PITCH, LONG, TRANS, and YAW).

### 3 MEDM screens

The MEDM screens provide parameter-based interaction to the realtime system through the EPICS interface. There are two main OMC MEDM screens. One is for overview of the OMC system. The other is specifically made for the OMC LSC/ASC control.

#### 3.1 OMC Overview screen

The OMC Overview screen provides access to the status of the OMC as well as the monitor for various OMC channels.

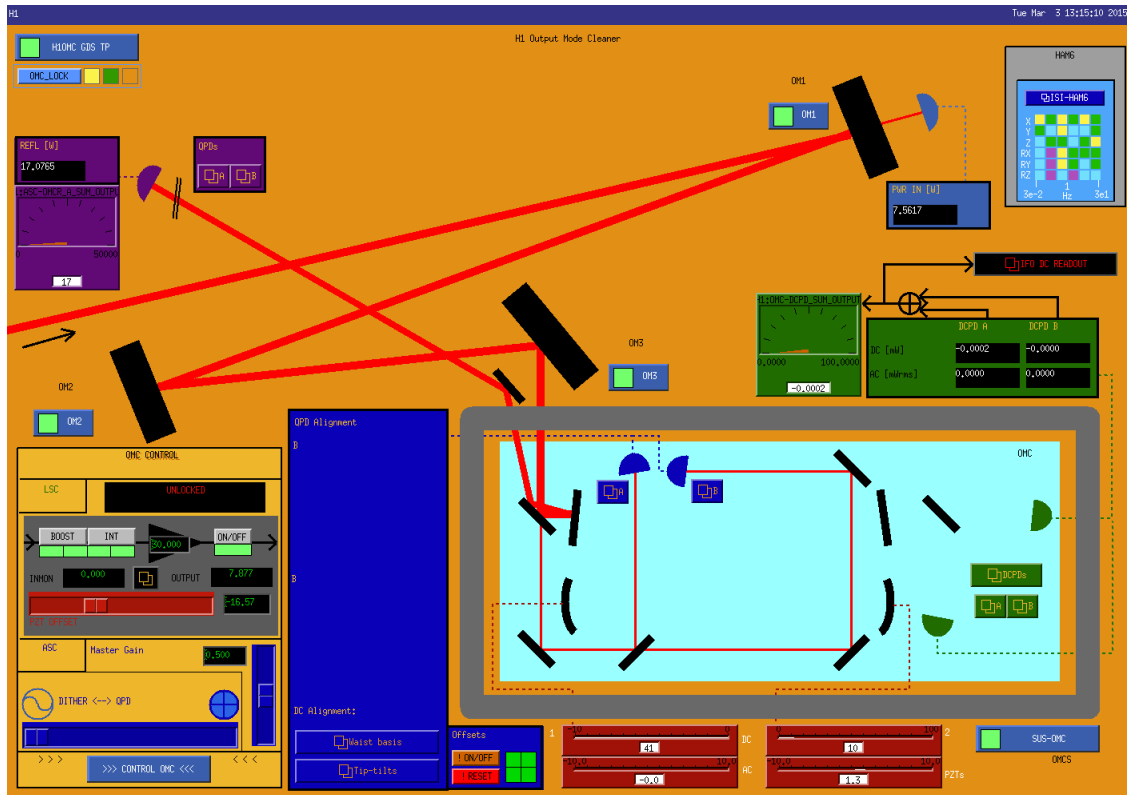


Figure 7: OMC Overview screen

The most noticeable graphics of the screen is the visual display of the OM mirrors and the OMC cavity. They indicate the status of the beams towards and in the OMC, based on the light levels on the monitor photodetectors.

The buttons distributed on the screen offer access to the filter modules for the monitors (OMC QPDs, OMC REFL QPDs, and DCPDs). The buttons named OM1, OM2, OM3, and SUS-OMC open the screens for the suspensions.

The XY plots on the blue background at the bottom left of the screen allow us to monitor the stability of the spots on the OMC QPDs. Thus this provides useful information about how the alignment servo loops are acting.

The black button at the right side opens the DC READOUT screen that allows us to set the values for the OMC READOUT subblock (Section 2.2.2).

The button at the very bottom left corner opens the screen for the OMC control (Section 3.2).



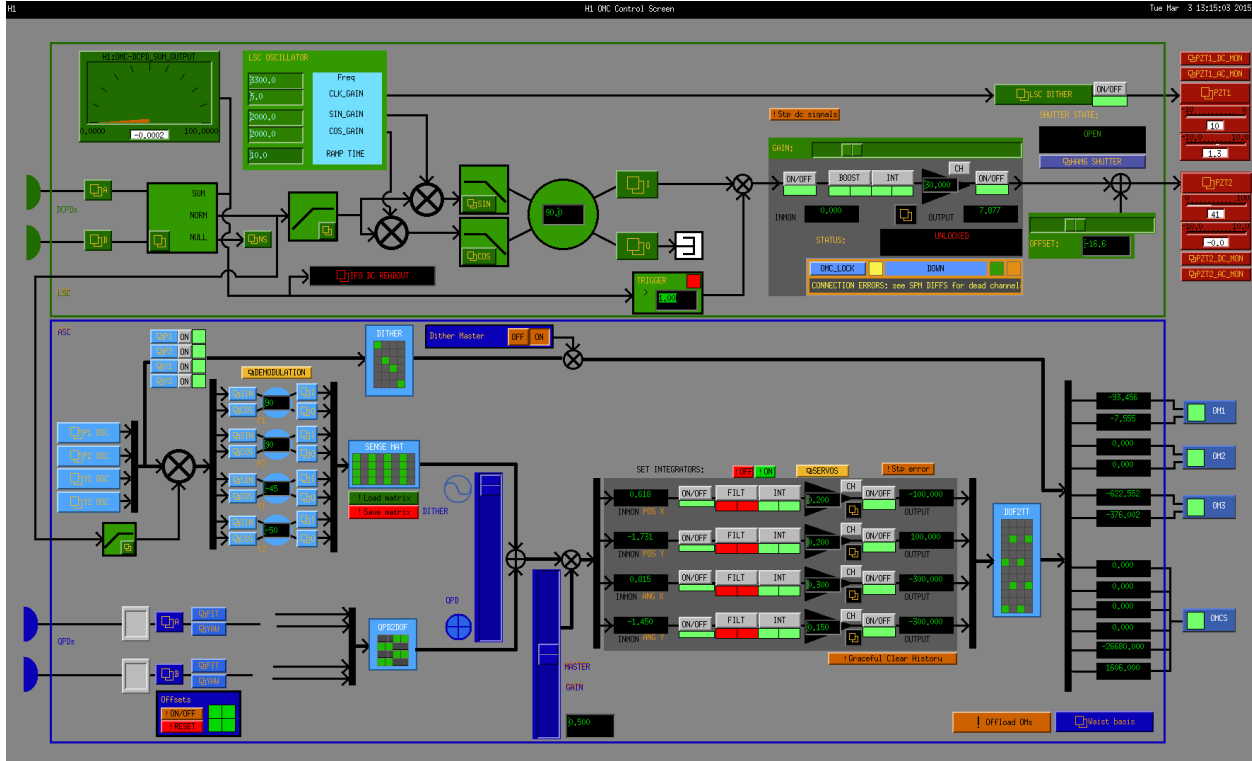


Figure 8: OMC DCPD

### 3.2 OMC Control screen

The OMC Control screen handles length and alignment control of the OMC cavity.

The top half of the screen (green section) provides parametric interface for the code described in Section 2.2.3. The right most part of the green section is the servo filter. The gain slider allows us to continuously change the gain of the OMC LSC loop. There also is an indicator for the fast shutter state. This also indicates the enable/disable state of the servo filter module. The offset slider provides the nominal offset of the PZT when one (i.e. human or a script) initially tries to lock the OMC.

The bottom half of the screen (blue section) provides a parametric interface for the code described in Section SEC:OMC-ASC. The input and output matrices are accessible from this screen. The two blue vertical sliders offer continuous tuning of the control gain as well as the ramping between QPD-based and dither-based ASC schemes. The servo filter section shows selected filter information. The full filter modules are accessible from the buttons in this section.

## References

- [1] R. Adhikari, M. Evans, T. Fricke, V. Frolov, K. Kawabe, N. Smith, and S. J. Waldman, *DC readout Normalization for Enhanced LIGO*, LIGO Document [T090023-v2](#), (2009).