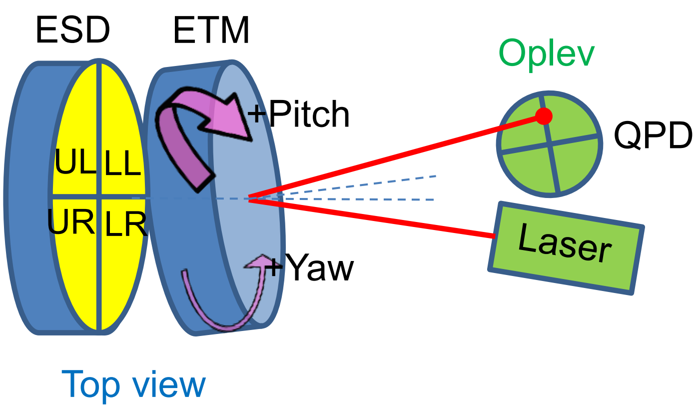
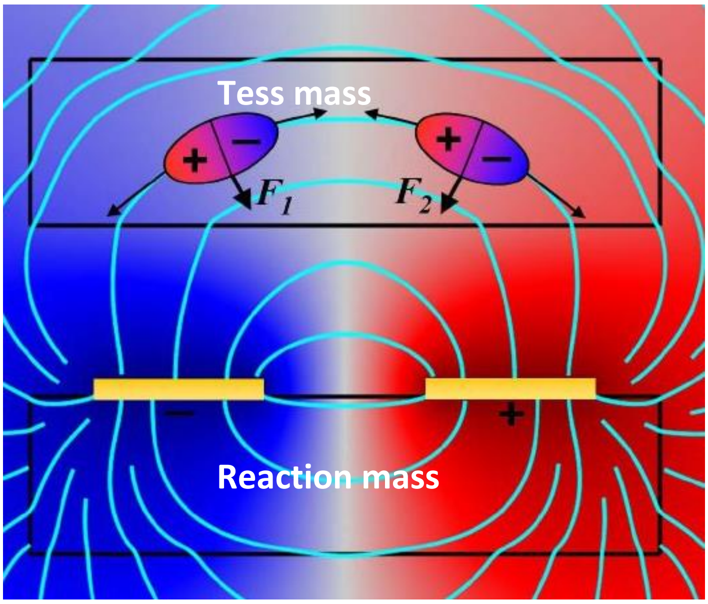
In this document I provide my interpretation on how to use the slope sign on the oplev deflection vs V BIAS ESD driving voltage to identify which quadrant is actually being driven. Remember that several wiring Kerfuffles (for instance see G1400578) caused that the ESD quadrant name on the CDS Epics channels and MEDM screens do not necessarily correspond with the physical quadrants they actually drive.

Let's start with how the actual quadrants of the ESD are meant to be labelled. The next plot is a top view of one test mass and the associated reaction mass with its coated ESD electrodes. The vertical quadrant labelling of top and bottom correspond to a conventional identification. Not so clear is the horizontal identification of left and right, which it was chosen as seen from the reaction mass point of view.



The ESD quadrant identification based on the slope of the oplev deflection vs VBIAS assumes that the positive pitch and yaw orientations (as depicted above) show positive signals in the oplev pitch and yaw deflection signals. Jeff has assured me that this is the case, as care is taken during the oplev installation, testing and calibration. During the oplev deflection measurements the magnitude of the deflection was observed by looking at the spectrum of the oplev pitch and yaw channels. The sign of the deflection it was given as being in phase or out of phase respect to the driving signal to the ESD quadrant channel (in putch and yaw respectively). This information was obtained by looking at the phase of the transfer function between driving signal and oplev deflection channels at the frequency of the injection. Always being sure that we were actually seeing properly the injection signal at the oplev by monitoring their coherence and this being at least 85% (lower coherence probably is also OK but then you will see that the noise will make the phase difference between positive and negative VBIAS not to be 180 degrees).

Now let's have a quick look at the working principle of an ESD. The potential difference on the ESD electrodes creates a fringing field across the test mass which induces dipoles on the mass dielectric molecules. These dipoles orientates such that the force is always attractive independently of the sign of the voltage in the electrodes. Because the induced dipole is proportional to the ESD potential difference (ΔV) then the attractive force is proportional to ΔV^2.



Taking into account that:

1. The test mass deflection due to the ESD driving signal is dominated by the dielectric polarization even with the presence of charge on the test mass.
2. The deflection vs VBIAS plots are measured such that the amplitude voltage of the driving signal is always smaller than the smaller VBIAS amplitude.

Then the physical effect of the driving signal is to just increase or decrease the attractive force between the reaction mass and the test mass as the total voltage on the electrodes (combination of VBIAS and driving voltage) is increased or decreased respectively.

Let's analyse, as an example, one quadrant (UL = upper left) for both pitch and yaw in the case of VBIAS being positive and negative (but fixed magnitude) and taking into account that the driving signal is sinusoidal. So at the time when the driving signal is null the attractive force between reaction mass and test mass is the same independent of VBIAS being + or – as long as its magnitude is fixed. As the driving signal goes through the positive half of an oscillation the attractive force will be higher if the VBIAS is – than if it is + because the potential difference (ΔV) will be higher, the exact opposite occurs when the driving signal goes through the negative half of the oscillation. If we take the reference orientation of the test mass as that corresponding to the driving signal being null then as we increase the attractive force on the UL quadrant we will see a negative pitch movement and a positive yaw movement. Opposite signs of pitch and yaw movements when the attractive force is decreased. So if we have a negative VBIAS we said that the positive half of the driving signal increases the attractive force and so the oplev deflection in pitch will be out of phase (thus negative deflection) with the driving signal while the yaw will be in phase (positive deflection). However when the VBIAS is positive then the positive half of the driving signal decreases the attractive force and so the oplev deflection in pitch is in phase (positive deflection) with the driving signal while the yaw will be out of phase (negative deflection). This translates to saying that the slope of *oplev deflection* vs *VBIAS* when driving quadrant UL in pitch and yaw is positive and negative respectively. Applying a similar analysis to the other 3 quadrants we get the next expected slope sign:

ESD driven quadrant	Pitch slope	Yaw slope
UL	**+**	**-**
UR	**+**	**+**
LL	**-**	**-**
LR	**-**	**+**

Now let's compare with the slopes observed during my ESD charge measurements both at ETMY and ETMX:

Slopes observed at ETMX:

ESD driven quadrant As labelled in CDS	Pitch slope	Yaw slope
UL	**-**	**-**
UR	**-**	**+**
LL	**+**	**-**
LR	**+**	**+**

This means that the CDS labelling is wrong in all cases. What is labelled as UL is actually the LL ESD quadrants, the labelled UR is actually the LR quadrant, the labelled LL is actually the UL quadrant and finally the labelled LR is actually the UR quadrant.

Slopes observed at ETMY:

ESD driven quadrant As labelled in CDS	Pitch slope	Yaw slope
UL	**-**	**-**
UR	**+**	**+**
LL	**+**	**-**
LR	**-**	**+**

This means that the CDS labelling is swapped between UL and LL in respect to the driving of the actual ESD quadrants.