Contiuing the temporary OpLev setup

After the team adjusted the position of the SR3 f0 keystone, we noted that the beam spot of the temporary OpLev shifted out of the QPD sensing area. This suggests couplings between the vertical degrees of freedom and the test mass tilt, in particular, the yaw direction. To compensate, the position of the QPD was re-adjusted by moving the whole QPD and traslation stage with it. I did another round of calibration for the QPD just to confirm the calibration factor obtained earlier (I had done once earlier right after we installed the OpLev onto the islands near the viewports but I didn't post it. That doesn't matter for now anyway).

See the next procedure for obtaining the diagonalization/calibration matrix (OL2EUL) for pitch and yaw only:

After the calibration, "part of the" calibration factor, which is in mm/counts, was obtained (see attachment for the calibration graph). From the graph, the factors for the vertical and horizontal axes are 0.002649 mm/counts and 0.002667 mm/counts respectively. Ingnore the signs for the moment because the signs do not matter as I defined coordinate system of the QPD roughly aligns with the line that the pitch and yaw of the payload creates. In the case of SR3, and looking at the QPD from the front, positive pitch would direct the beam upward and positive yaw would direct the beam leftward. But since we are using a steering mirror to direct the beam to the QPD, the image of the vertical direction will be inverted so positive pitch means downwards in the QPD coordinate. Therefore, I defined the matrix such that values due to light hitting seg 1 and 2 of the QPD positive vertical (and s3, s4 negative), contrary to what we have set before. (see sr3_oplev_seg.png). Similarly, I set s1 and s4 for positive horizontal and s2 and s3 negative horizontal.

To avoid confusion, please note that, instead of the true pitch and yaw, P and Y in the MEDM screen refer to vertical direction and horizontal direction in the QPD respectively. And, for the rest of the discussion, I will refer pitch and yaw to the traces of the beam spot casting on the QPD due to the motion of pitch and yaw respectively. If everything was aligned perfectly, the vertical and horizontal axes (refer to y and x from now on) would coincide with the pitch and yaw axes. However, they will not be aligned in reality. One of the reasons is that the QPD itself is not perfectly leveled. Or, this could due to the fact that the steering mirror was installed in such a way that it has tilt in the roll direction, which would cast a rotated image to the QPD. So, the pitch and yaw axes would appear to be rotated with respect to the y and x axes of the QPD. Since the output of the QPD gives information with respect to its own coordinate system, we need to use coordinate transformation (rotation in particular) for obtaining pitch and yaw. And then, we can convert pitch and yaw to true pitch and yaw by introducing the optical arm length which is the length of the beam from the payload to the QPD. For instance, 2 * true pitch = pitch / (effective arm length).

We filled 1s and -1s into the actuation matrix of the TM OSEMs (see sr3_tm_act.png) and confirmed that the directions are correct by actuating the test mass and comparing outputs from the QPD. In particular, we checked if positive pitch actuation gives positive pitch output and the same goes for yaw.

To obtain the correct transformation matrix between the xy axis and the yaw-pitch axis, I applied pure yaw incremental offsets (using the actuation coils of the TM recoil mass) to the optics and obtained the yaw axis with respect to the xy system. I did the same for pitch. (see qpd_vs_yp.png). As can be shown from the plot, the pitch axis and the yaw axis are not perfectly diagonal to each other. For the purpose of measuring transfer functions in yaw direction, I ignored the pitch axis I plotted and assumed there exists an imaginary pitch axis which is perpendicular to the red yaw axis I plotted. And from here, I can calculate the angle between the two coordinate systems which is -2.5911322 degrees.

Finally, thanks to Hirata-san, I obtained the length from the center of the payload to the upper viewport which is 990.54 mm. And I measured the distance from the viewport to the steering mirror (300 mm) as well as the distance from the steering mirror to the QPD (160 mm). Meanwhile, the beam bounces off the payload with a 36.9 degrees angle to the horizontal (see SR3_Assy_oplev.jpg). So the effective arm length for the pitch sensing is:

$r_p = 990.54+300+160$ mm = 1450.54 mm = 1.45054 m

And the effective arm length for yaw sensing is:

$r_y = (990.54+300)\cos(36.9(\text{degrees})) + 160$ mm = 1192.02 mm = 1.119202 m

And then we can insert the matrix product of the inverse of the arm length, the rotation matrix and the calibration factors in the OL2EUL matrix in the MEDM screen (see OL2EUL_MEDM.png) from the numbers obtained using the equation for pure Yaw and Pitch (see OL2EUL.png attached) with:
theta = -2.5911322 * pi/180 rads
C_x = 0.002667 mm/counts
C_y = 0.002649 mm/counts
K = 10^6 urad/rad * 10^-3 m/mm = 10^3 urad/rad*m/mm

However, for the moment, the pitch calculated does not represent the real pitch because I did coordinate transformation according to the yaw axis. We are still not sure why the real pitch axis is not perpendicular to the yaw axis. So we might need to further investigate this problem.

Since the electromagnetic actuators in the TM recoil mass are operating in open loop mode, it is highly possible that they might react differently to the same voltage level. Therefore, when I attempted to actuate the test mass with pure yaw, the test mass would also move in longitudinal direction and pitch direction if the four electromagnetic actuators are not perfectly identical to each other. As a result, I didn’t actually obtain the pure yaw and pure pitch axes in the adforementioned step (the axes from qpd_vs_yp.png). From the graph, the test mass will move in negative yaw direction when I apply a pure pitch and It will move in the negative pitch direction when I apply a positive yaw. I attempted and failed to calculate the coefficients for the actuation of the coils. I won’t be able to tell the exact coeffients unless we have a working OpLev (we need both tilt and length) since this act as the sensors of the coils. But, I can for sure tell that the strength of H2 plus H4 are the weaker than that of H1 plus H3.

I understand that in principle we should use the power spectrum of the yaw and pitch channel to derive the correct rotational transformation matrix. I will return to that method after another attempt of obtaining the pitch and yaw axis on the QPD by using actuation from the IM to put the TM in pure pitch and yaw direction.