SUBSYSTEM: SXT Engineering Unit

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DESCRIPTION: OAP2 Thermal Soak and 1G Errors

Summary

- The vertical assembly configuration is acceptable using any of the design alternatives considered, however we need to understand the effects of the support load path in more detail.

- Effects of optic bonding on the performance have not been addressed analytically; we recommend an experimental program for this although we may try to make a rough analytical assessment.

- The better X-ray test configuration is the “edge” configuration, but somewhat more difficult to implement than the “flat” configuration. More work to design and analyze an “edge” mount is needed. In all cases, the errors exceed the preliminary allocation and we need to revise the budget.

- The 1G and thermal errors can be reduced significantly by masking the aperture to a smaller wedge angle. We should plan to run X-ray tests with two or more different masks with different wedge angles. This will help us separate 1G and thermal errors from optic errors.

- Thermal errors are somewhat less than predicted last year (based on a rigid housing model), but we still will need to control the assembly-to-test bulk temperature difference to about one degree C.

- Bonding the two edges of the optics at their axial mid-points improves 1G horizontal performance, but makes the thermally driven errors worse.

- The “windows” for interferometry do not have a large structural impact, but will have a thermal impact during both assembly and X-ray test. We should plan to make thermal enclosures for both configurations.

Introduction

We have analyzed OAP2 performance with respect to gravity and thermal errors. The following load cases were analyzed:

1. 1G Vertical (gravity along optical axis, alignment orientation) – Figure 1
2. 1G Flat (gravity normal to optical axis, optic concave UP) – Figure 2
3. 1G Edge (gravity normal to optical axis, optic on edge) – Figure 3
4. 1 Degree C soak (operational temperature 1 degree C different from assembly temperature), assuming material properties:

   Housing (Titanium): 9.5×10^{-6}

   (Or 8.6×10^{-6} per Jeff Stewart)

   Optics (D236 Glass): 7.2×10^{-6}

The following design configurations were examined:

1. Integral housings (NO interferometer windows)
2. P and H Housings with 92.6mm x 175mm windows for interferometry (see Figure 1)
3. Double the nominal housing wall thickness (¾ inch vs. 3/8 inch)
4. Axial support centered on wall in vertical gravity case (vs. support offset from wall centerline on a foot).

OAP2 Error Budget

The current OAP2 X-ray test error budget is shown in Figure 4. It has allocations for gravity deformations in X-ray test at 2.5 arc-seconds (HPD), for housing/glass CTE mismatch at 5 arc-seconds (HPD) and for assembly/bonding strain at 3 arc-seconds. Our analyses address all of the above terms except for the bonding portion of assembly strain (which requires experiments).

Overall Results

Plots of our current results (in terms of optic half power diameter) are shown in Figures 5, 6 and 7. The results are plotted vs. aperture width (in degrees) ranging from 30 degrees to 60 degrees (the 60 degree case is not physically realizable). Since the errors scale roughly with aperture size we should plan to run X-ray tests using a couple of different masks with different apertures. This will tend to separate the optic errors from 1G and thermal errors.

Thermal Soak Results

Figure 5 shows 1 degree C soak results for the four design configurations listed above, for both the nominal housing CTE of $9.5x10^{-6}$ and the lower CTE of $8.6x10^{-6}$ which was reported by Jeff Stewart in his e-mail of October 16. As a reference point, thermal case results presented last year (December 2001) showed a sensitivity of about 5 arc-seconds (HPD) per 1ppm differential strain. This earlier case assumed that the housing was rigid. Using a housing CTE value of $9.5x10^{-6}$ we would expect an HPD of about 11.5 arc-seconds (for the 60 degree aperture) based on the earlier analysis. In our current analysis we obtained HPD values between 3 and 4 arc-seconds. This is due to the introduction of housing flexibility, which reduces the constraint on the glass optics. If we assume the lower housing CTE we get about 2 arc-seconds HPD for the full aperture.

It is interesting to note that the addition of windows in the P and H housings or the doubling of the wall thickness have very little effect on performance, however, elimination of the edge bond reduces the thermal sensitivity be a factor of 2. From a thermal standpoint, it is better not to add this edge bond. Another feature to note is that reduction of the aperture wedge angle improves performance significantly. This is due to fact that much of the optic distortion is near the two edges (next to the housing walls), as shown in Figures 8 and 9.

Horizontal Gravity – X-ray Test Results

Horizontal gravity case results are shown in Figure 6. A summary of results for a 50 degree wedge angle aperture is given in Table 1, sorted by HPD. There are two general sets of results, one for the “flat” X-ray test Configuration and another for the “edge” configuration. For comparison, the 1G horizontal results from last December (for a rigid housing with edge bonds) ranged between 1.4 and 3.4 arc-seconds (HPD). Without the edge bonds, the HPD went up to 11.4 (“flat” case) arc-seconds and 7.4 arc-seconds (“edge” case).

The results for the horizontal gravity case listed in Table 1 are close together, except for the “flat” case with no edge bonds. The HPD for this case is more than double any of the others. This result makes us consider the “edge” case for X-ray testing, either with or without the edge bonds.

Horizontal Gravity Cases at 50 Degree Apertures					
Configuration	**Wall Thickness**	**Window**	**Edge Bonds**	**HPD**	**Aperture**
Flat	Double	No	Yes	4.43	50
Edge	Double	No	Yes	5.41	50
Edge	Nominal	No	Yes	5.90	50
Flat	Nominal	Yes	Yes	5.96	50
Edge	Nominal	Yes	Yes	5.97	50
Flat	Nominal	No	Yes	7.37	50
Edge	Nominal	No	No	7.40	50
Flat	Nominal	No	No	17.20	50

Table 1 – Horizontal Gravity Case Summary at 50 degree Aperture

All of the horizontal gravity results exceed the error budget allocation of 2.5 arc-seconds (HPD). This was an early allocation based on rigid housing results. We plan to revise this allocation based on current results.

Vertical Results

Results from the vertical cases are shown in Figure 7. Eight cases are shown, divided into two groups of four by the assumed support condition. In the “offset” support condition the support loads are carried through three “feet” with the load path offset from the wall centerline by several mm. In the “centered” support condition the load path is in the center of the wall. Four sub-cases were run fro each support condition; 1) no windows, 2) windows, 3) double wall and 4) no edge bonds. As expected, the HPD values are all very low (under 1.5 arc-second) except for the centered support with windows case, for which the HPD is on the order of 2.5 arc-seconds. This case seems anomalous since one would expect that the centered support would perform better. We plan to investigate this further.

The 1G vertical strain will be bonded into the optics at assembly time. The resulting performance impact falls below the allocation of 3 arc-seconds (HPD) for assembly/bonding strain. However, this analysis did not address the effects of epoxy cure and shrinkage on the optical performance. This is potentially a large impact due to the flexibility of the optics. We should address this issue by experiments.

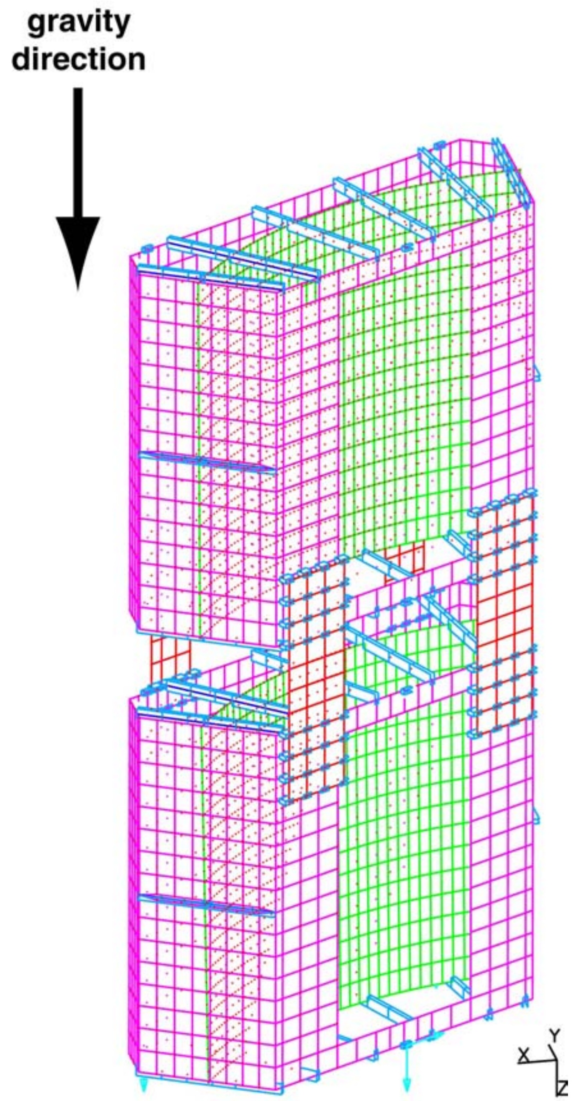


Figure 1 – 1G Vertical Case (with Interferometer windows)

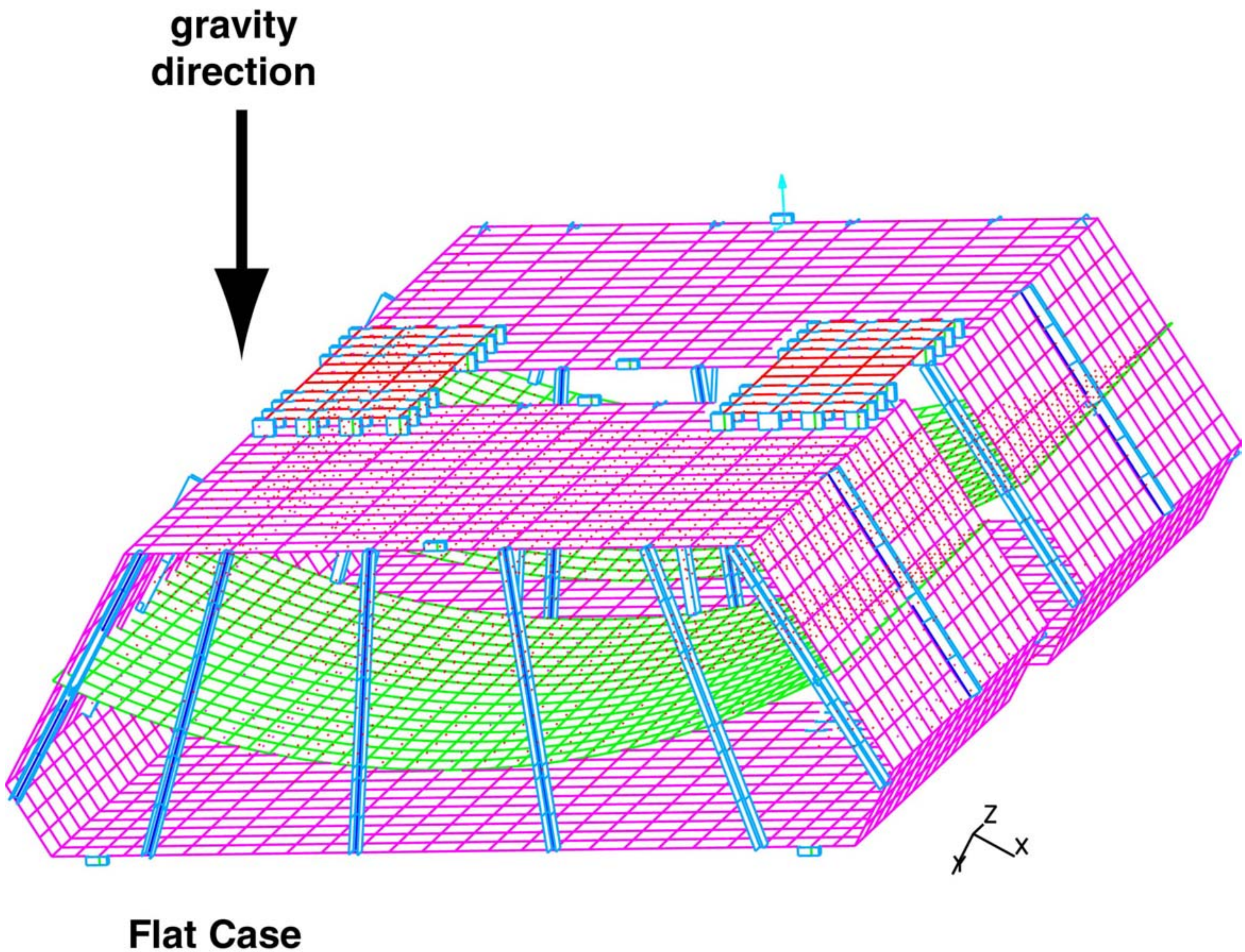


Figure 2 – 1G Flat Case (no windows)

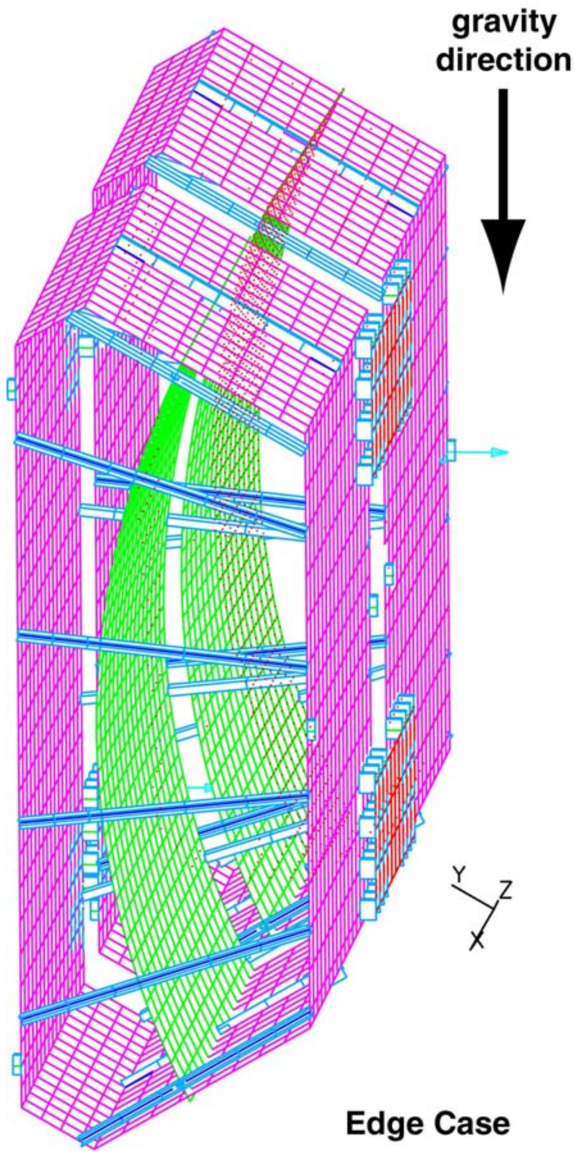


Figure 3 – 1G Edge Case (no windows)

OAP2							
ITEM (HPD - arcsec)	**Budget**			**Prediction**			**NOTES**
Image Resolution - As Tested	12.38			19.70			
X-ray test errors		2.69			2.69		
Gravity			2.50			2.50	From Davis Gravity analysis
Test Equipment			1.00			1.00	
OAP thermally induced errors (ΔT driven)		5.39			5.39		
Housing/glass CTE mismatch			5.00			5.00	Need 0.4 degC temp error
Epoxy/glass bi-layer effects			2.00			2.00	400µm glass, 20µm epoxy, 1 deg C
Material stability effects		1.00			1.00		
OAP Mirror, As-built		10.77			18.73		
Assembly (bonding) strain			3.00			3.00	Estimate
Alignment Errors (Using CDA)			3.00			2.50	From CDA Alignment Sheet
Optical Elements			9.90			18.32	From Optics Sheet

Figure 4 – OAP Error Allocations

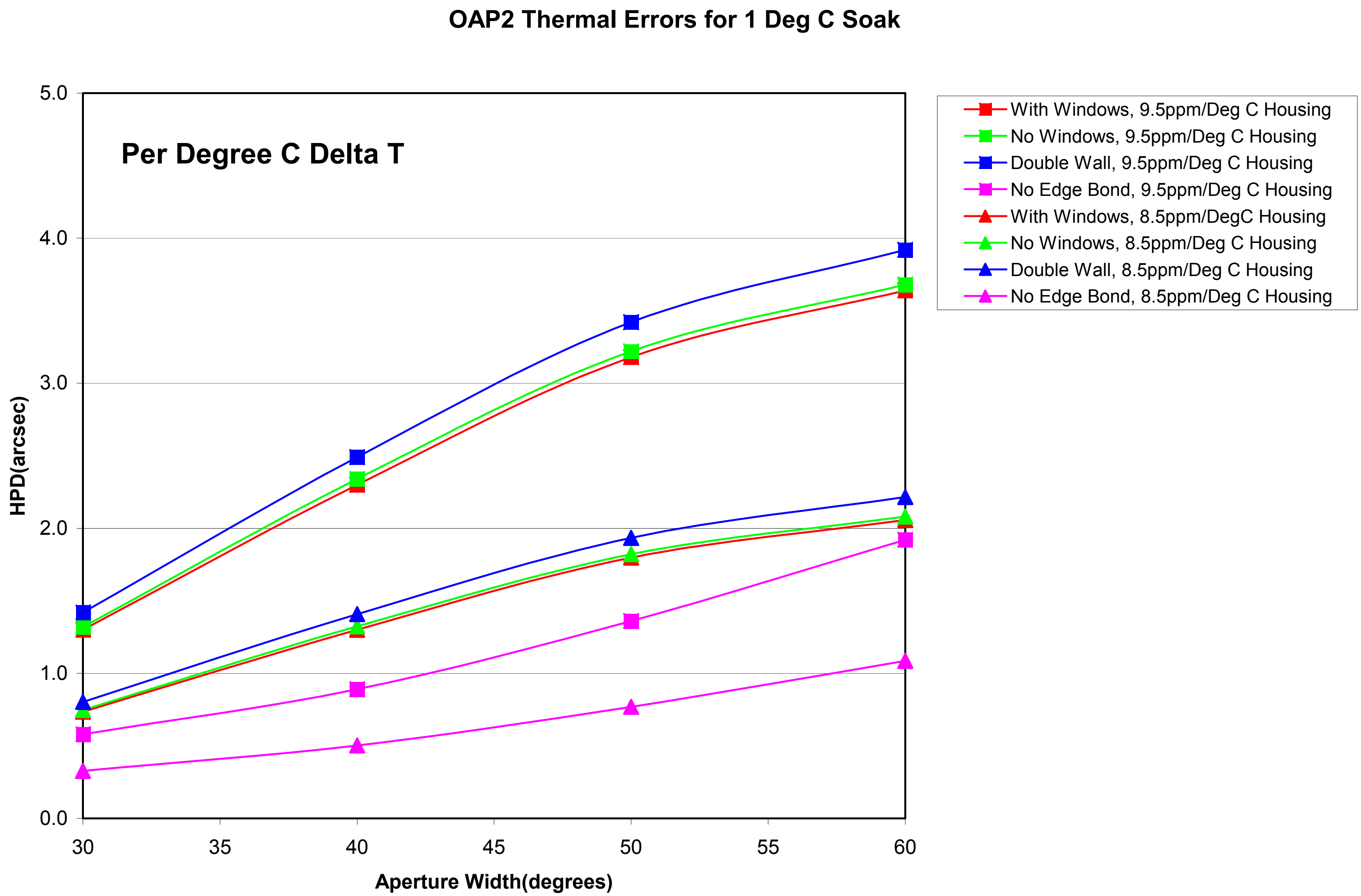


Figure 5 – Thermal Case Results

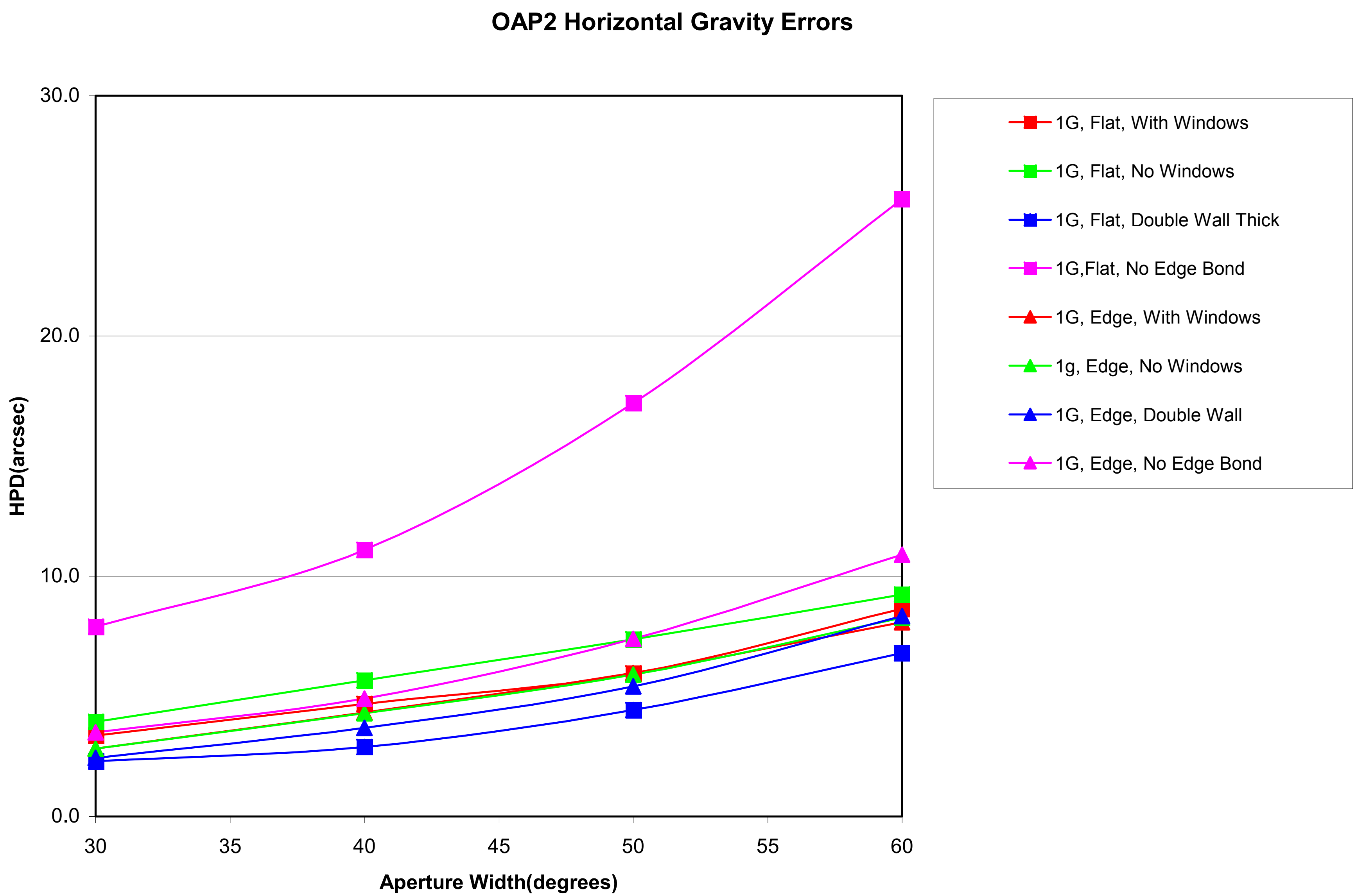
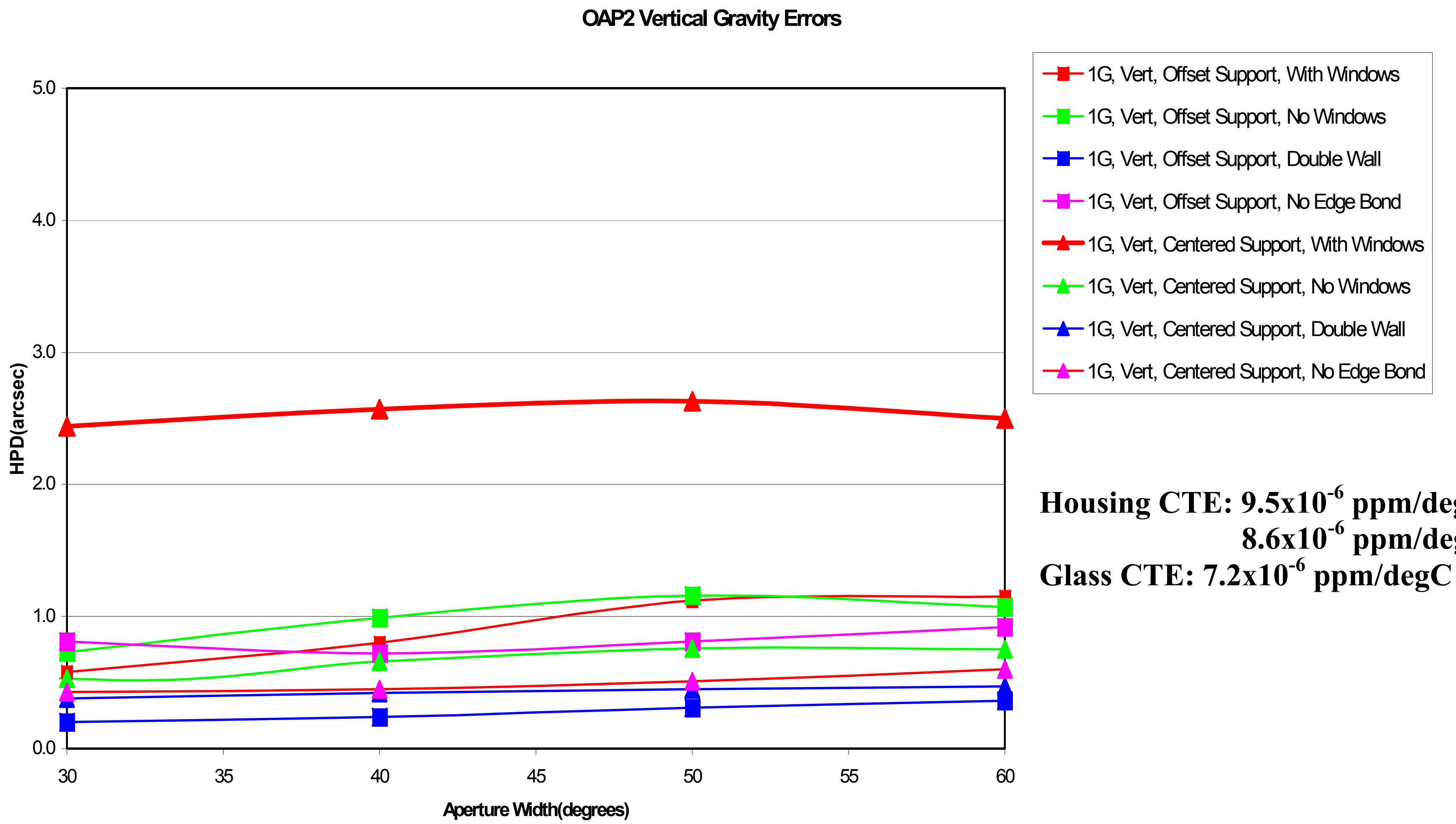


Figure 6 – Horizontal Gravity Case Results



Housing CTE: 9.5×10^{-6} ppm/degC
8.6×10^{-6} ppm/degC
Glass CTE: 7.2×10^{-6} ppm/degC

Figure 7 – Vertical Gravity Case Results

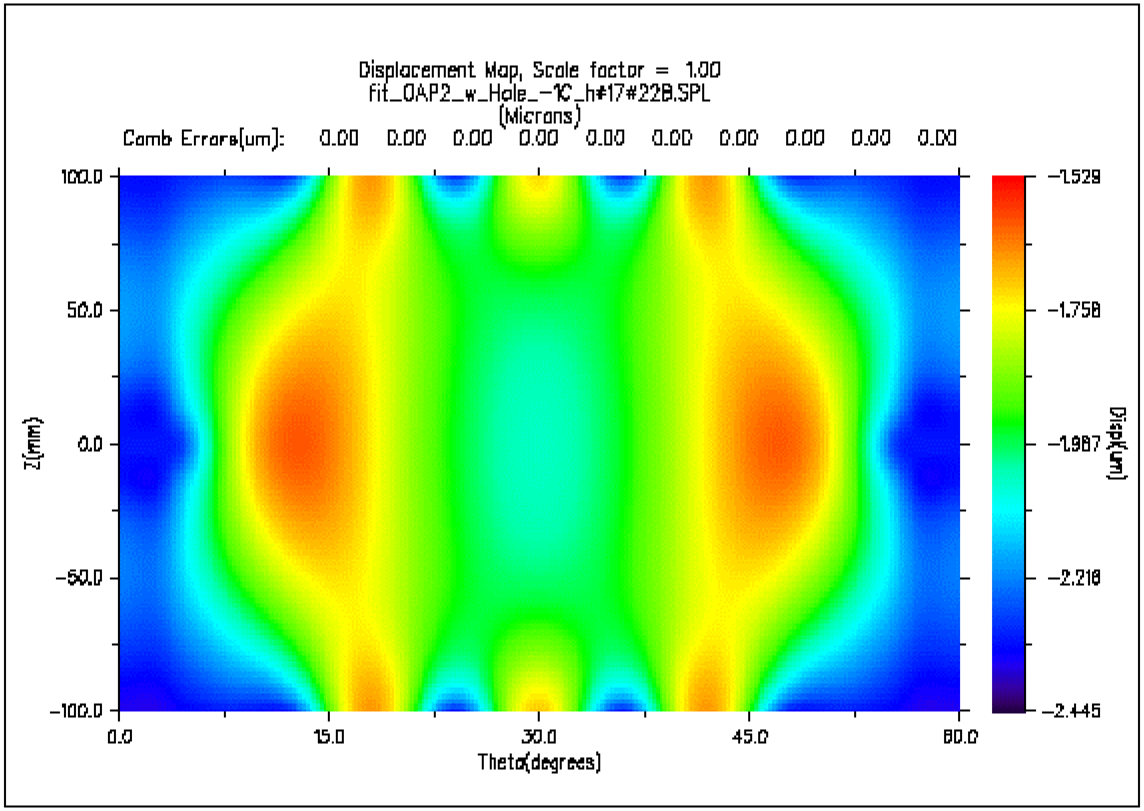


Figure 8 – Optic Displacement for Thermal Case

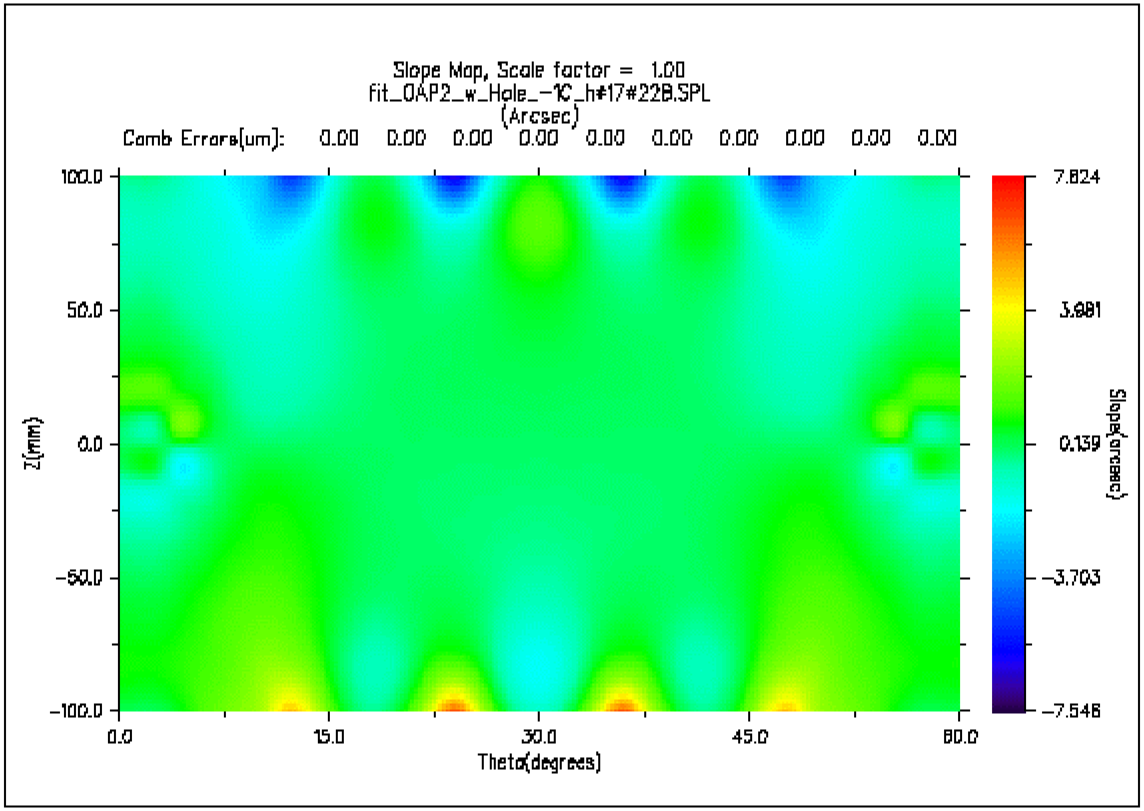


Figure 9 – Optic Slope for Thermal Case