

Thermal Analysis of the DES Camera Focal Plate

High Energy Physics Division

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1. Introduction

A design specification for the DES Camera focal plate is to keep the deformation of the plate to less than 30 microns under operating conditions. Figure 1 shows the assembly of the focal plate, the support bipods and support ring, and the copper braid assemblies. Several studies were done to examine the deformation of the focal plate under different thermal and structural constraints. Simple hand calculations were also performed as a check of the finite element model and results. The main goal of this analysis was to determine the deformation of the plate and to understand what thermal and structural conditions are causing the deformation.

2. Description of Cases

A detailed finite element model of the focal plate assembly was created. The boundary conditions used in all of the analysis were the following:

- Radiation heat transfer from the front surface of the focal plate to the C5 lens. An emissivity of 0.85 was used and an ambient temperature of 263K (based on earlier thermal analysis)
- The support ring was set to a temperature of 22C
- The supporting ring for the bipods was rigidly fixed in place
- The bottom of the copper braids were set to a temperature of -120C

The following cases were examined:

Case 1a:

- Focal Plate simply supported along the outside diameter
- Bipods and support ring eliminated from model
- Copper braid assembly mounted to plate but with no restraint

Case 1b:

- Same as Case 1a but with the ends of the copper braids restrained from movement in Z.
- Modulus of copper braids equal to 0.1 times the modulus of copper

Case 1c:

- Same as Case 1b but with the modulus of the copper braid increased to 0.5 times the modulus of copper.

Case 2a:

- Bipods and support ring included in the model with the support ring rigidly fixed in place.
- Copper braid assembly mounted to plate but not restrained from movement in Z.

Case 2b:

- Same as Case 2a but with the ends of the copper braid assembly restrained from movement in Z. A modulus for the braids equal to 0.10 times the modulus of copper was used.

Case 2c:

- Same as Case 2b but with a modulus for the copper braid equal to 0.5 times the modulus of copper.

3. Results

The deformation of the focal plate and the temperature distribution within the plate were calculated for each case and are described below.

3.1. Case 1a

Figure 2 shows the temperature distribution within the copper braid assembly and focal plate. This temperature distribution corresponds well with hand calculations.

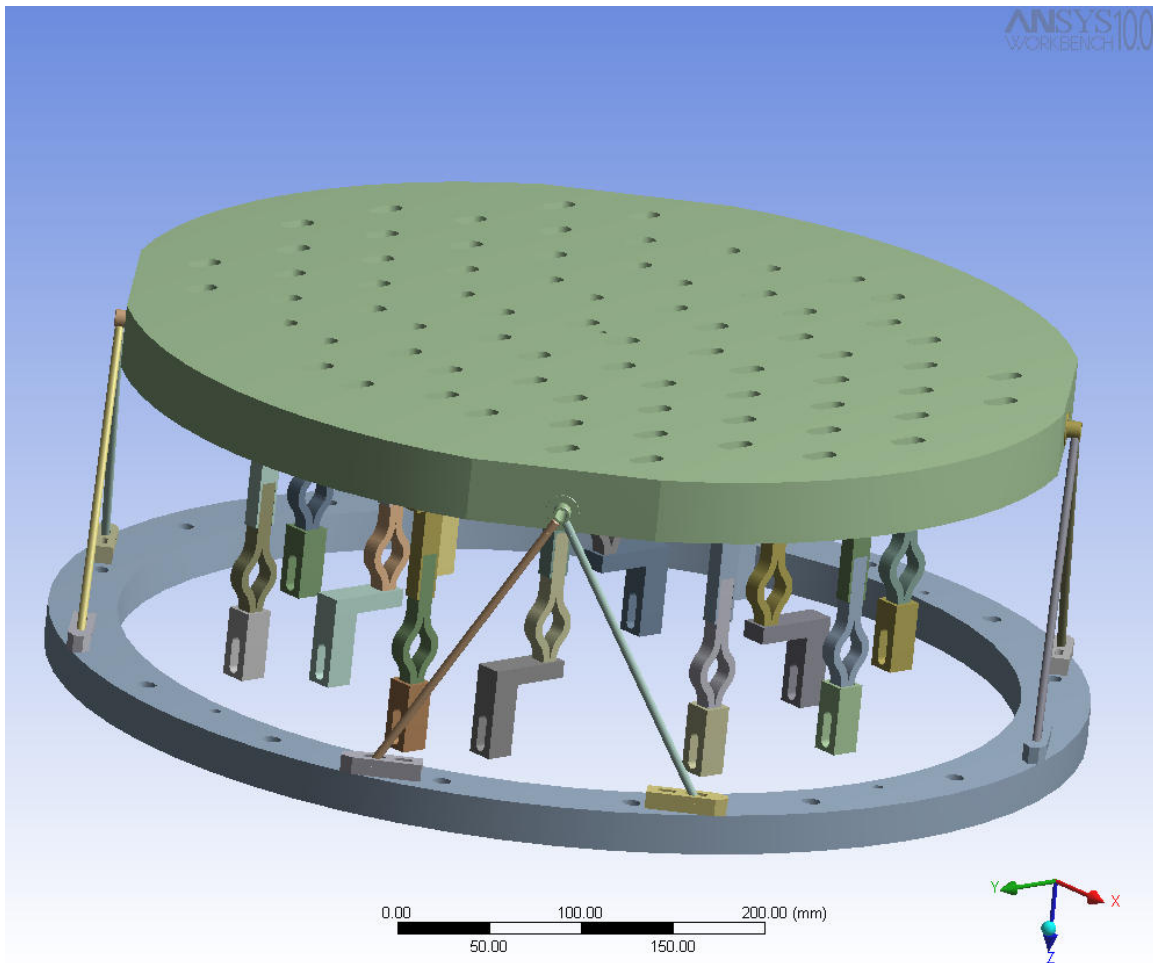


Figure 1 – Model of Focal Plane

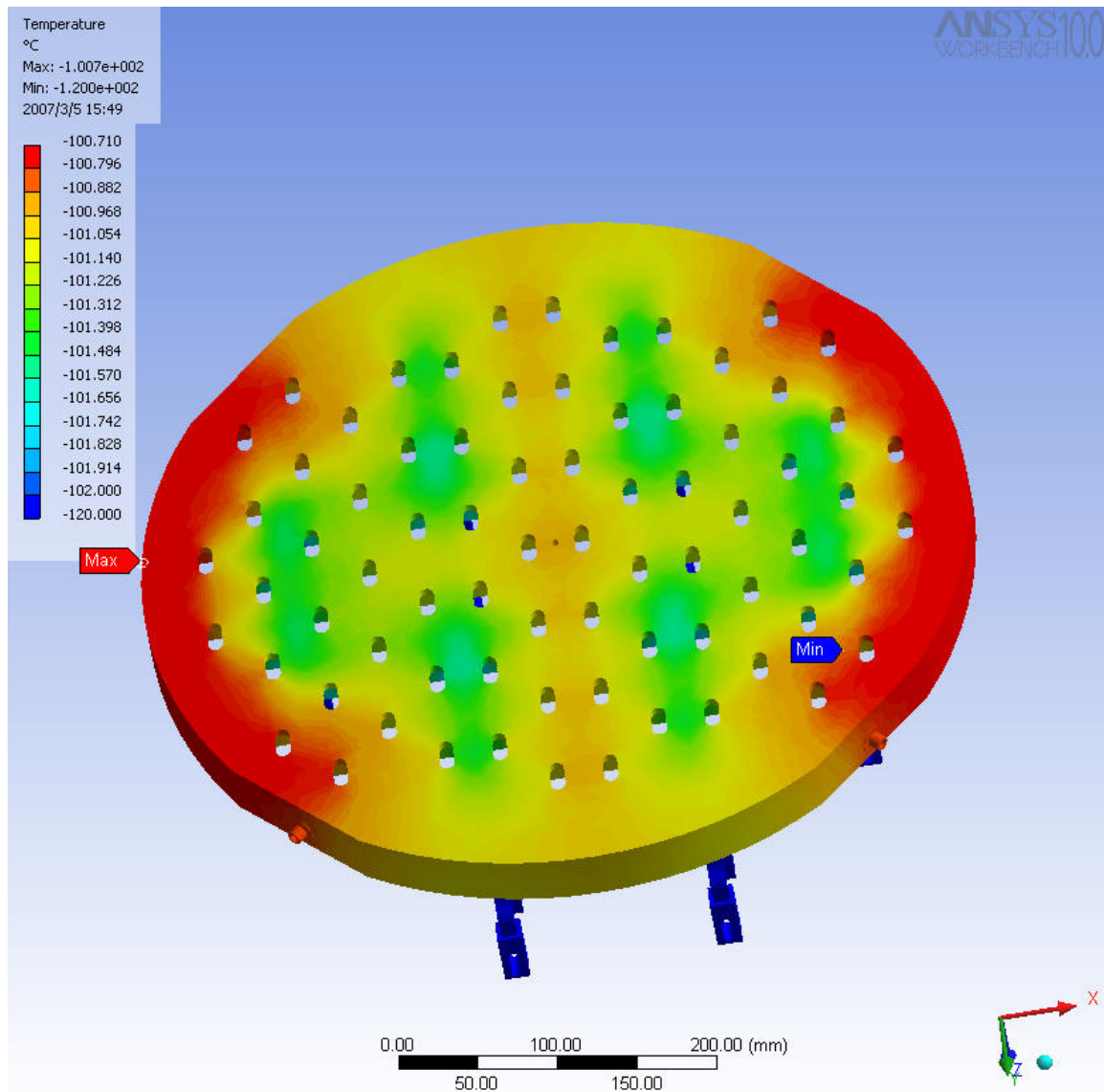


Figure 2 Temperature Distribution for Case 1a.

Figure 3 shows the deformation of the focal plate. In Case 1a the focal plate is simply supported on its outer radius so there is no rigid body motion of the plate. The deformations within the plate itself are very small, less than 0.003mm. These small deformations correspond with hand calculations of a flat plate subjected to a temperature differential.

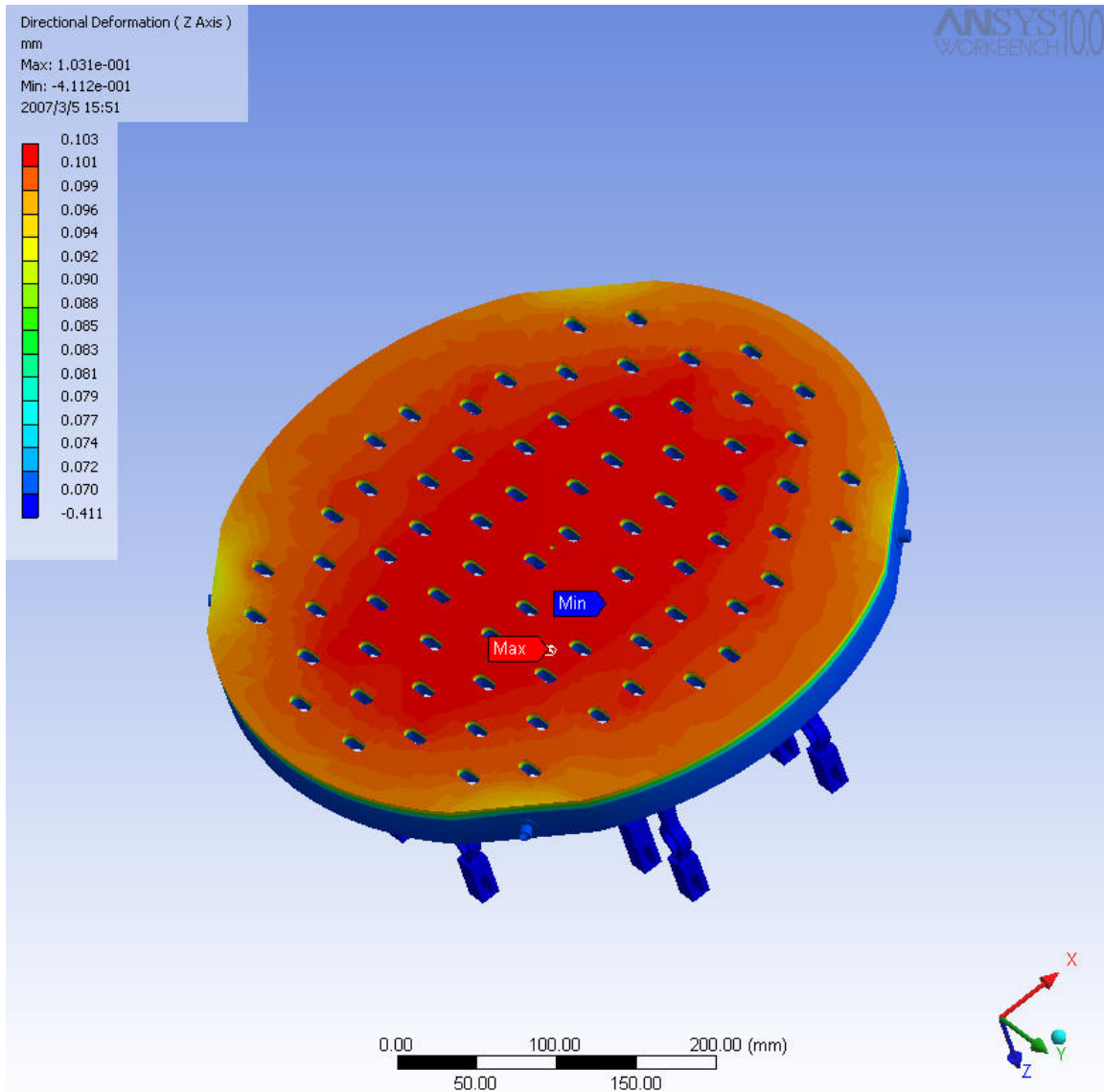


Figure 3 – Z deformation of Focal Plate for Case 1A

3.2. Case 1b

In Case 1b the ends of the copper braid assemblies are restrained from motion in X, Y, and Z. The temperature distribution does not change within the structure but the deformations of the focal plate increase significantly to a total out of flatness of approximately 0.3mm. Figure 4 shows the deformation in Z of the focal plate. Figure 4 shows that the center of the plate is pulled downward due to the shrinkage of the copper braid assembly. The amount of deformation is determined by the relative stiffness of the copper braid assembly and the focal plate. In Case 1b the stiffness of the copper braids was equal to 0.1 times the modulus of copper.

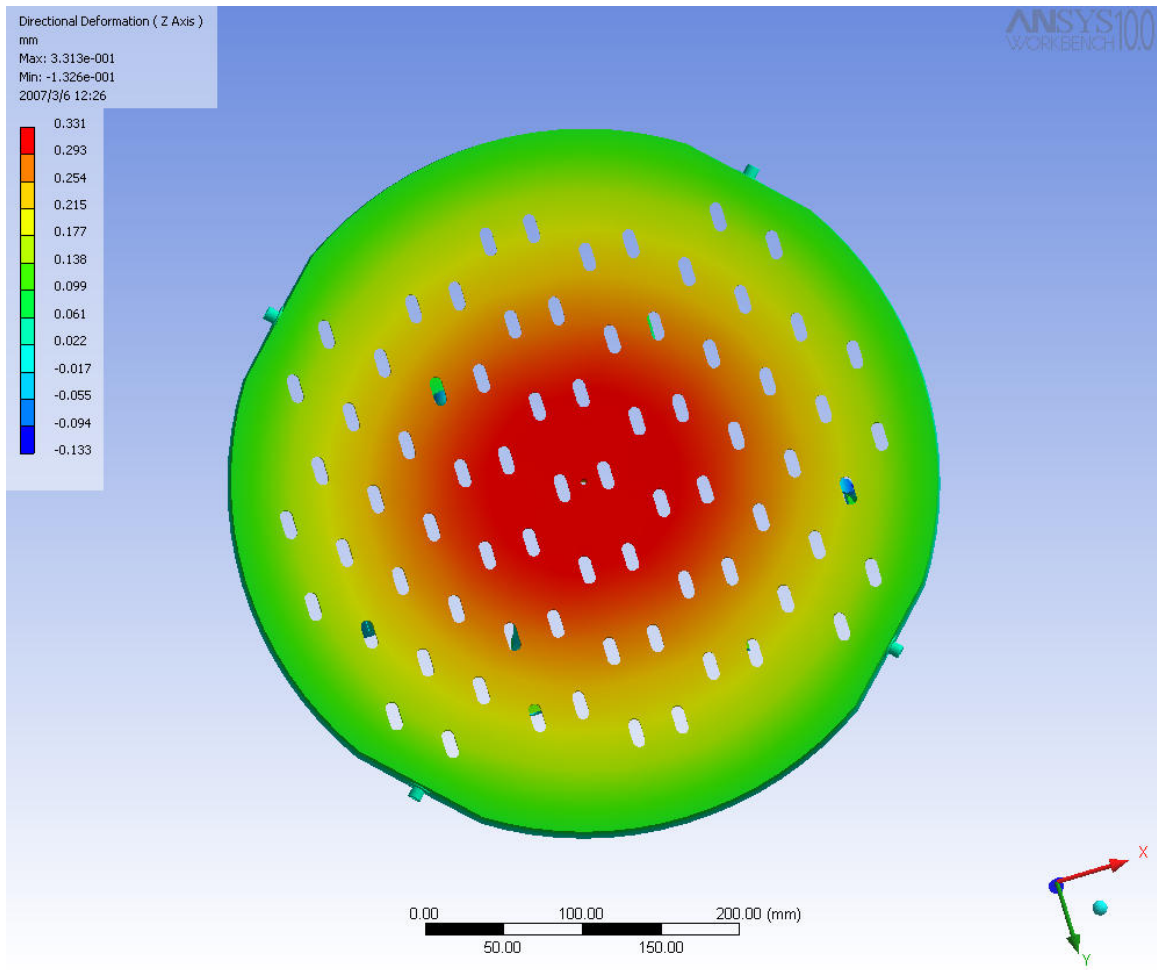


Figure 4 – Z Deformation of Focal Plate for Case 1b

3.3. Case 1C

Figure 5 shows the deformation of the focal plate when the modulus of the copper braid was increased to 0.5 times the modulus of copper. The deformation of the plate is due to the shrinkage of the copper braid assembly and the relative stiffness of the focal plate and the copper braid. Since the modulus of the copper braid increased the deformation of the focal plate also increased to nearly 0.5mm.

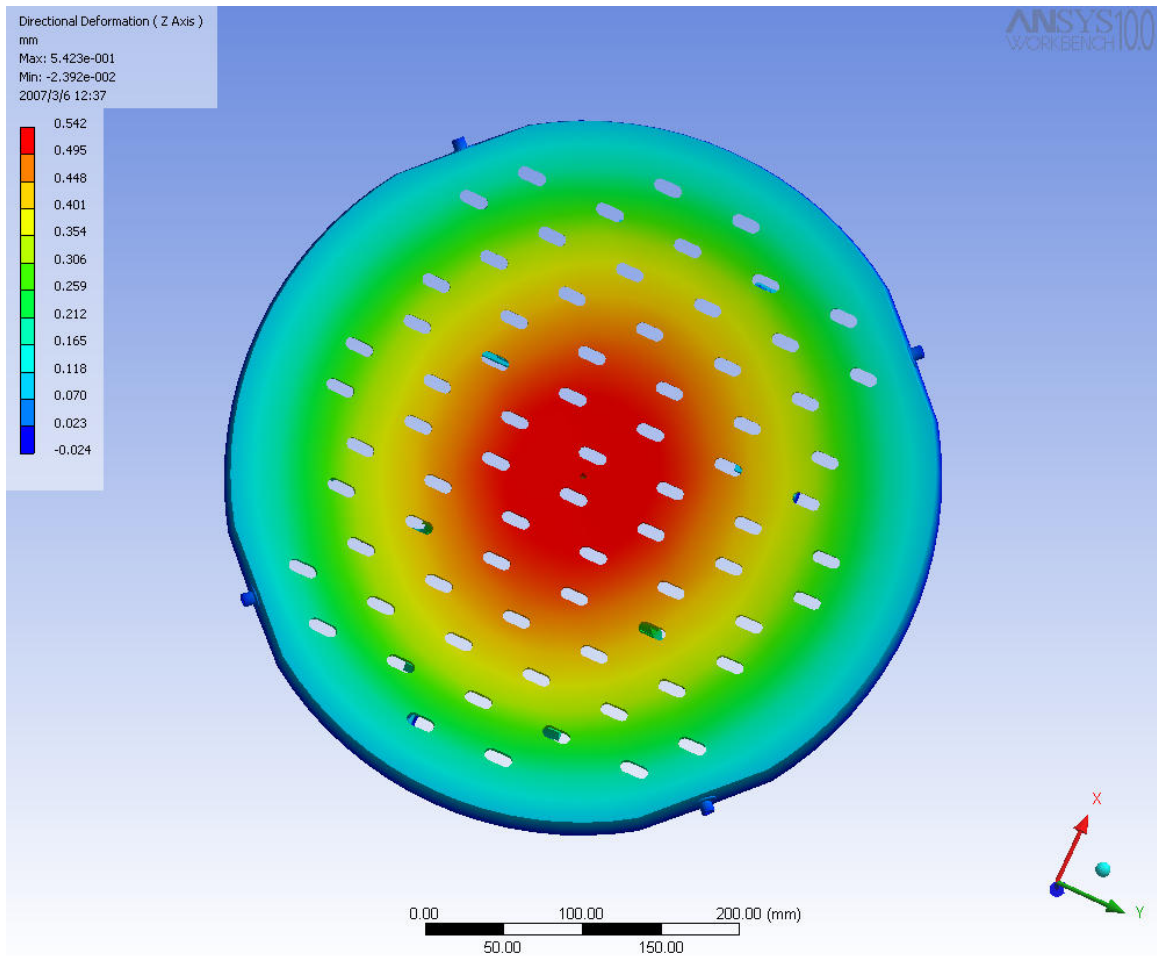


Figure 5 – Z Direction Deformation of Focal Plate in Case 1C

3.4. Case 2a

Case 2a is similar to Case 1a except now the focal plate is supported by the bipod structure rather than being simply supported along its outer diameter. The copper braid assembly is not restrained at all in this case and is free to move with the focal plate. Figure 6 shows the temperature distribution in the focal plate.

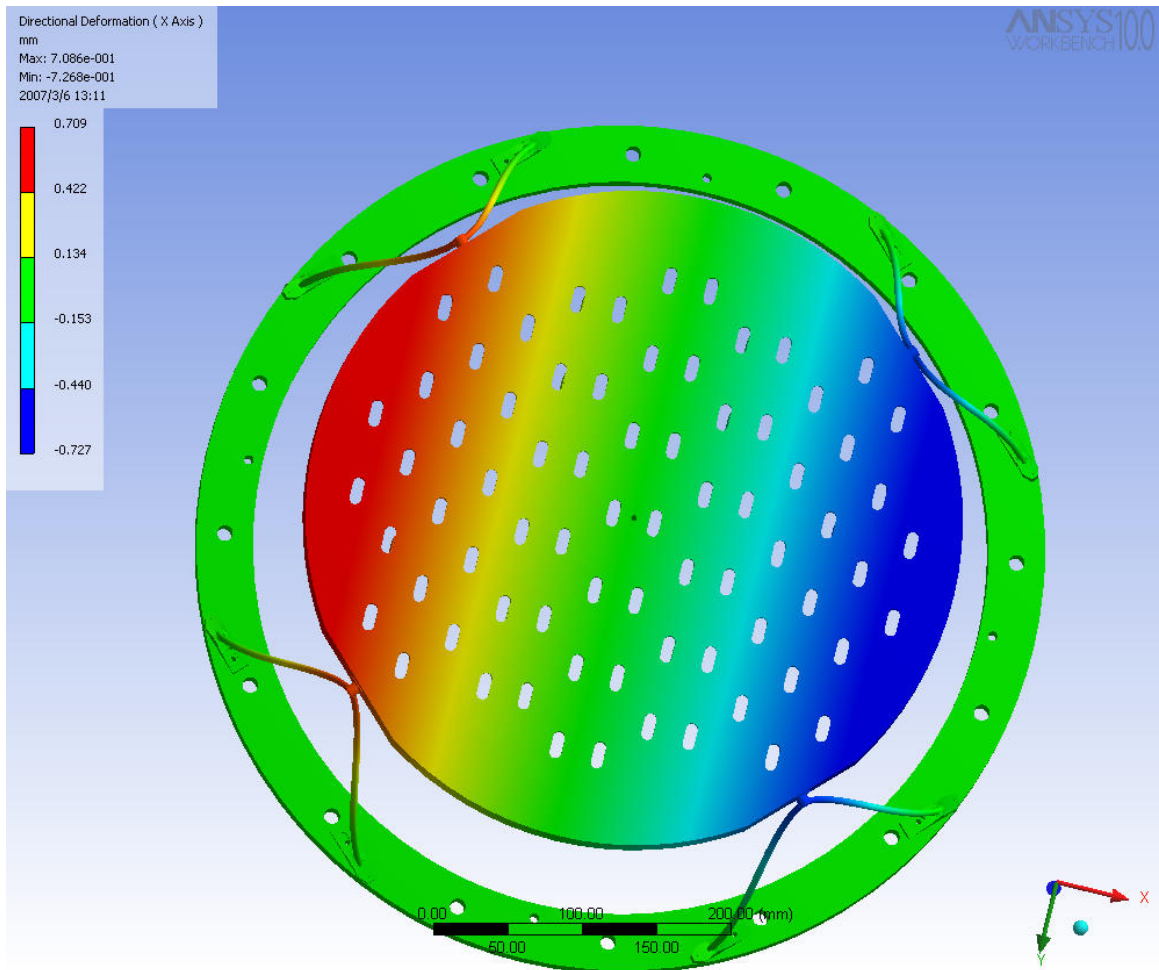


Figure 7 – Deformation in the X Direction for Case 2a

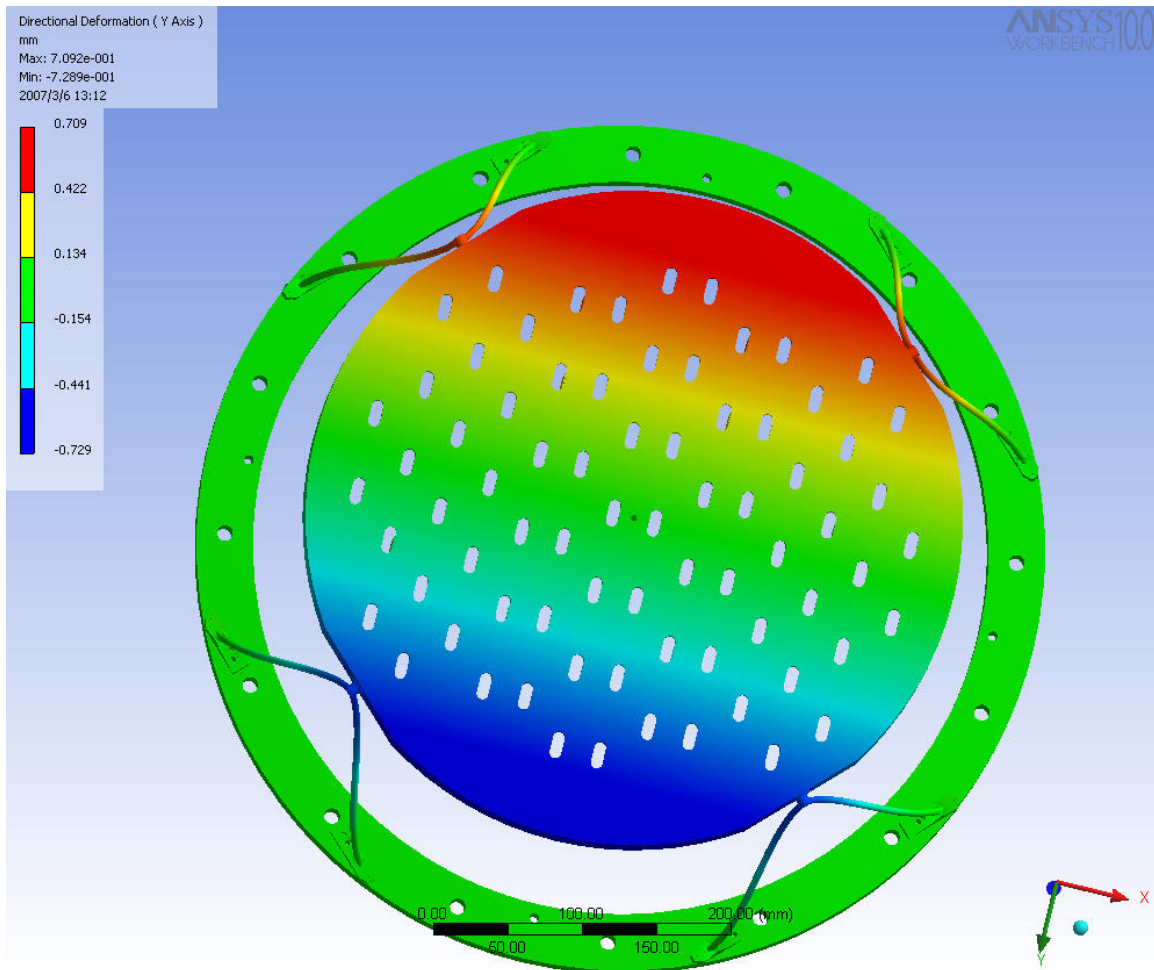


Figure 8 – Deformation in the Y Direction for Case 2a

Figures 7 and 8 show the deformation of the focal plate in the X and Y directions. It can be seen that the deformation in X and Y are simply due to shrinkage of the plate. These figures also show that there is a small ($\sim 0.02\text{mm}$) asymmetry to the deformations. This asymmetry is due to rigid body motion of the plate as it moves laterally. The focal plate is supported by the bipods which do not provide much lateral stiffness, therefore, the plate is free to move laterally which accounts for the asymmetry that is seen.

Figure 9 shows the deformation in the Z direction for Case 2a. Since the copper braid assembly is not restrained it does not apply any force on the focal plate. The displacement shown in Figure 9 is simply due to rigid body motion of the focal plate and not due to any deformation of the plate itself. This rigid body motion is due to the deformation of the bipods.

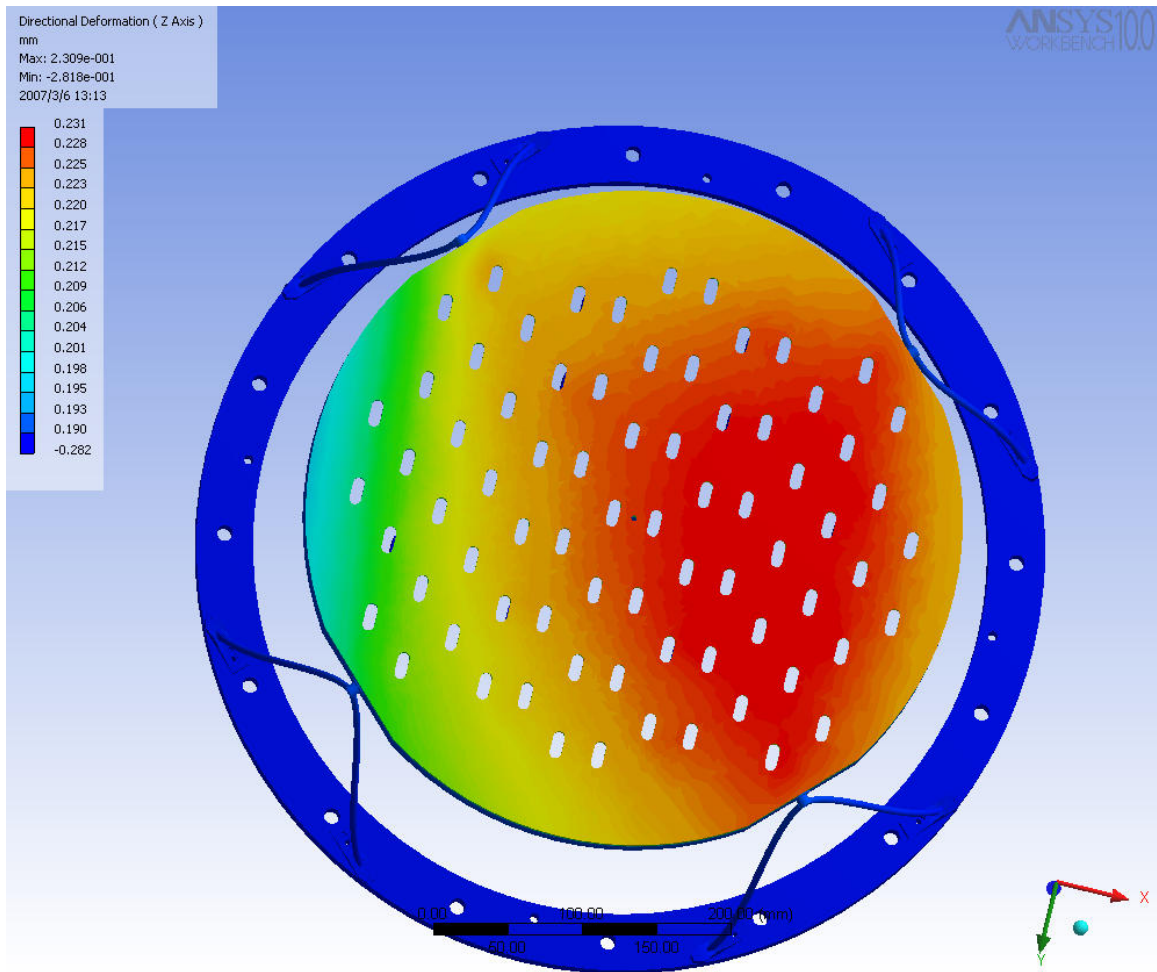


Figure 9 – Deformation in the Z direction for Case 2a

3.5. Case 2b

In Case 2b the ends of the copper braid assemblies are restrained from motion in X, Y, and Z. Figure 10 and 11 show the deformation of the focal plate in the X and Y directions. The asymmetry occurs again due to small lateral stiffness of the bipods.

Figure 12 shows the deformation in Z. The focal plate has a rigid body motion displacement as well as out of flatness deformation of approximately 0.1mm. This is approximately half of the out of flatness found in Case 1b, which indicates that the bipods are not stiff enough to resist the contraction of the copper braids and therefore deform with the braid assemblies.

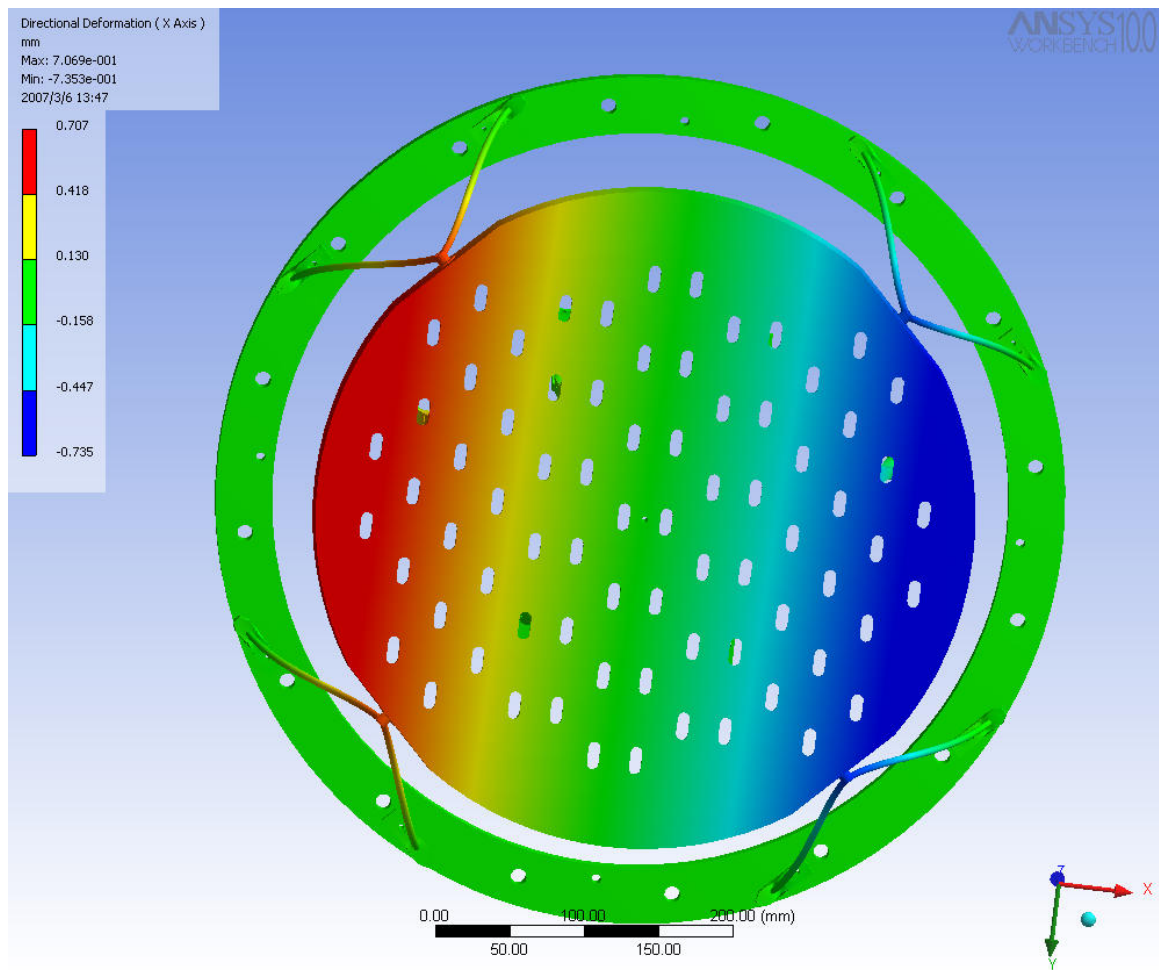


Figure 10 – Deformation in the X Direction for Case 2b

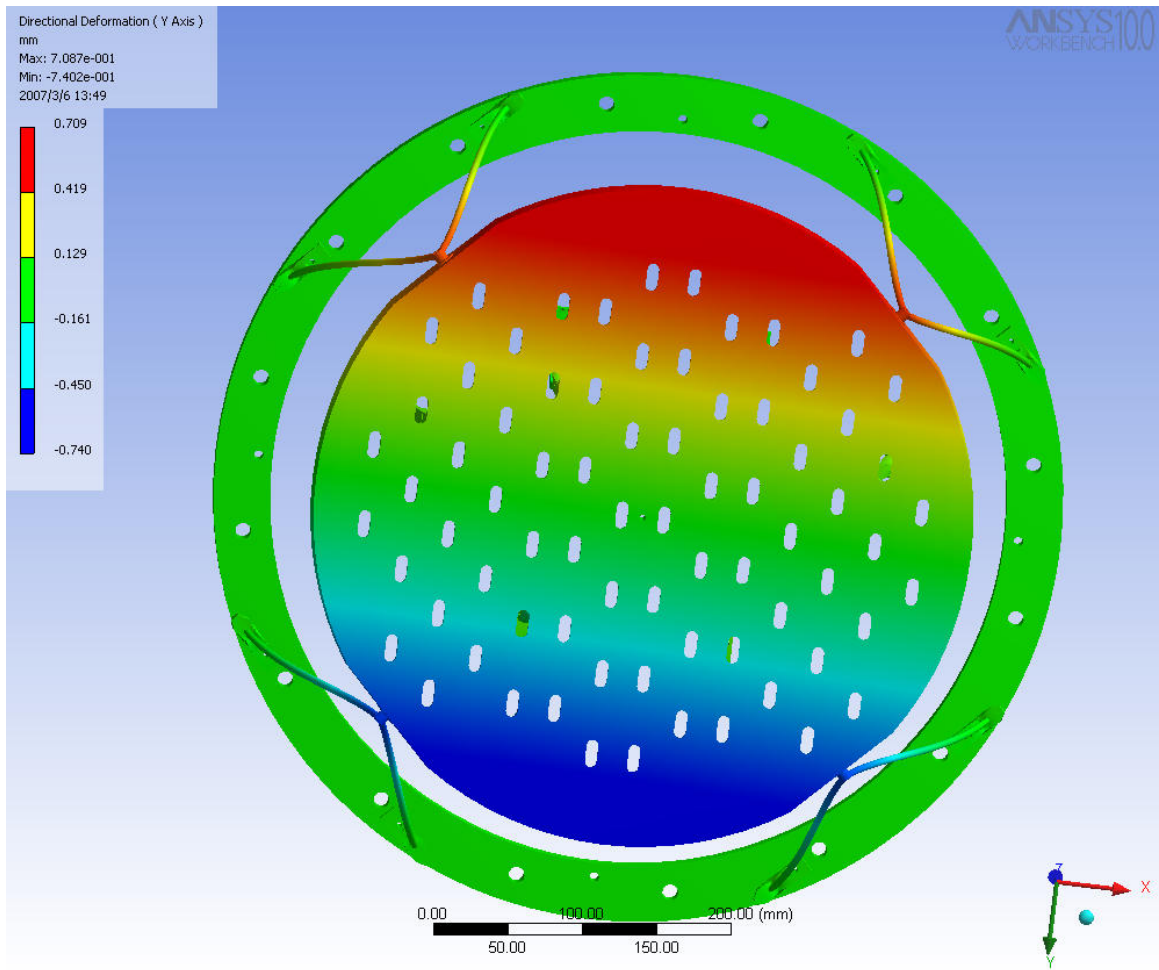


Figure 11 – Deformation in the Y direction for Case 2b

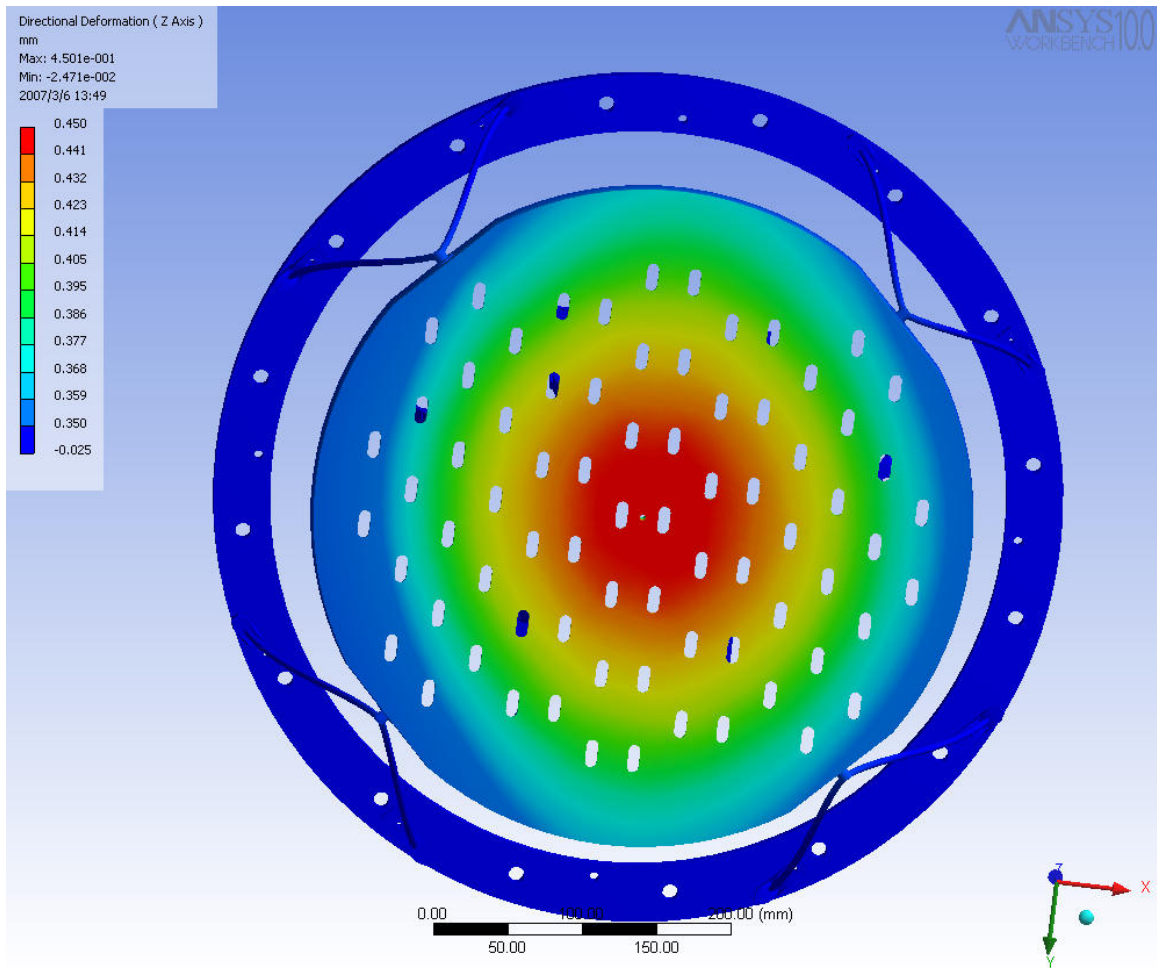


Figure 12 – Deformation in Z of Case 2b

3.6. Case 2c

In Case 2C the modulus of the copper braid assemblies is increased. The deformation in X and Y are shown in Figures 13 and 14. Figure 15 shows the deformation in the Z direction and the out of flatness of the plate has increased to nearly .16mm. This deformation is approximately a factor of 3 less than that found in Case 1C which indicates that the bipods are deforming and cannot resist the contraction of the copper braids.

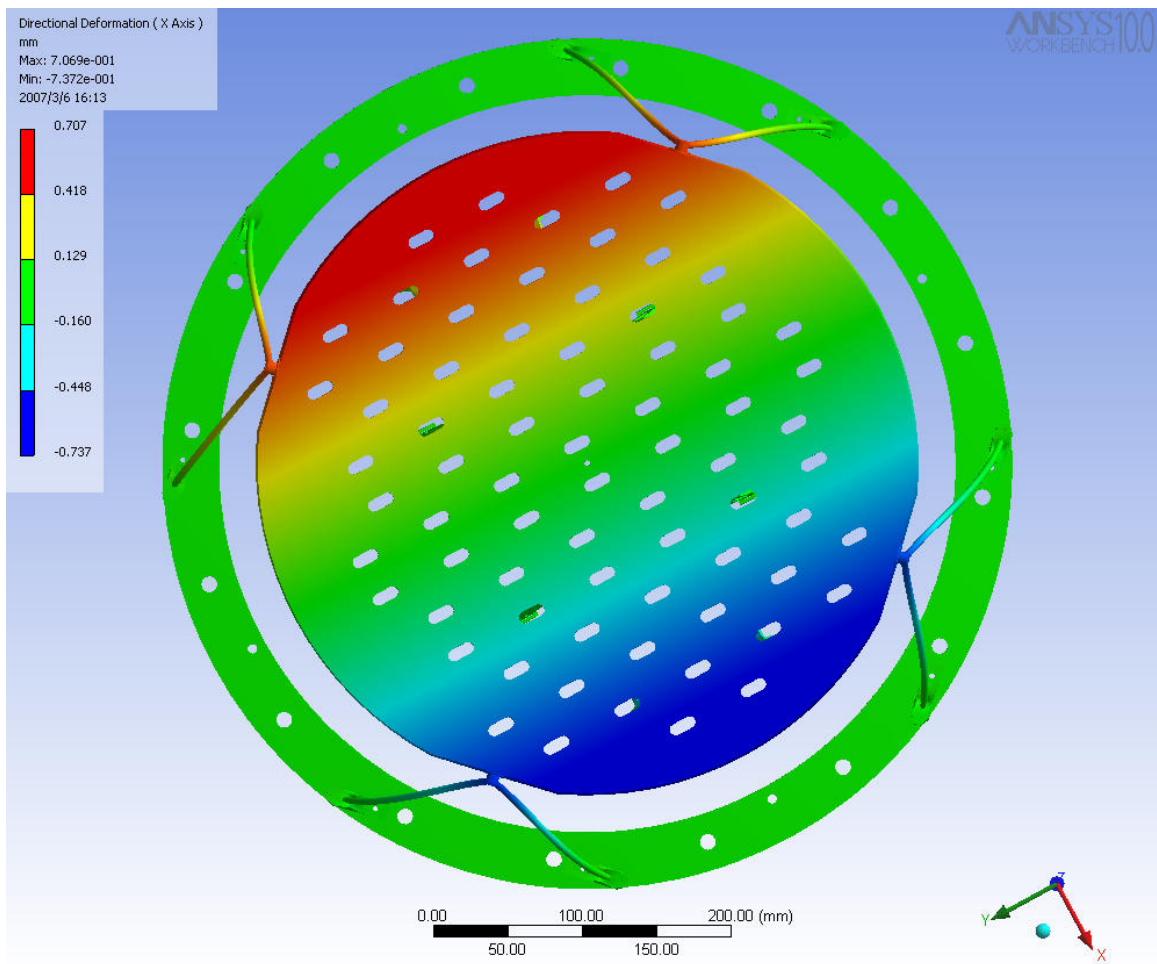


Figure 13 – Deformation in X of Case 2C

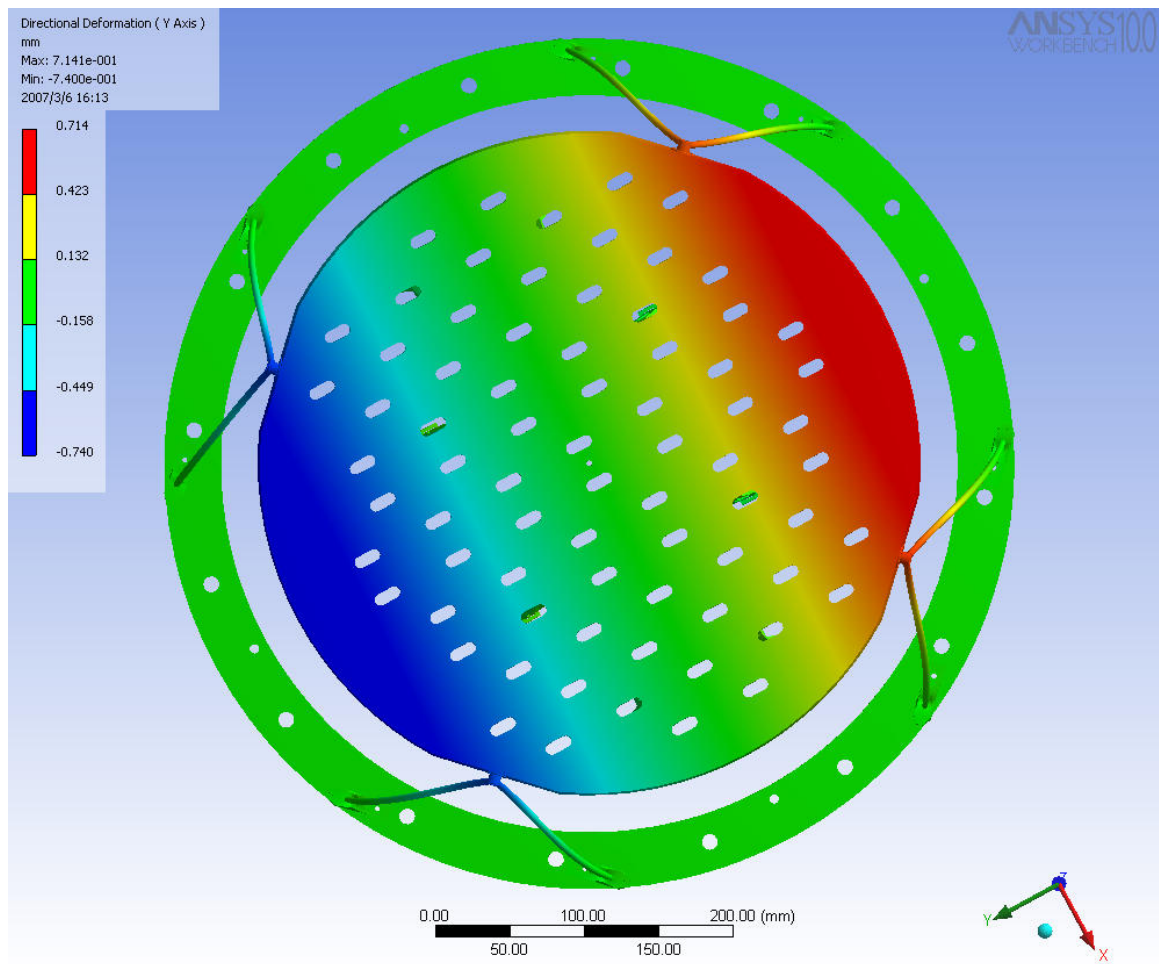


Figure 14 – Deformation in Y of Case 2C

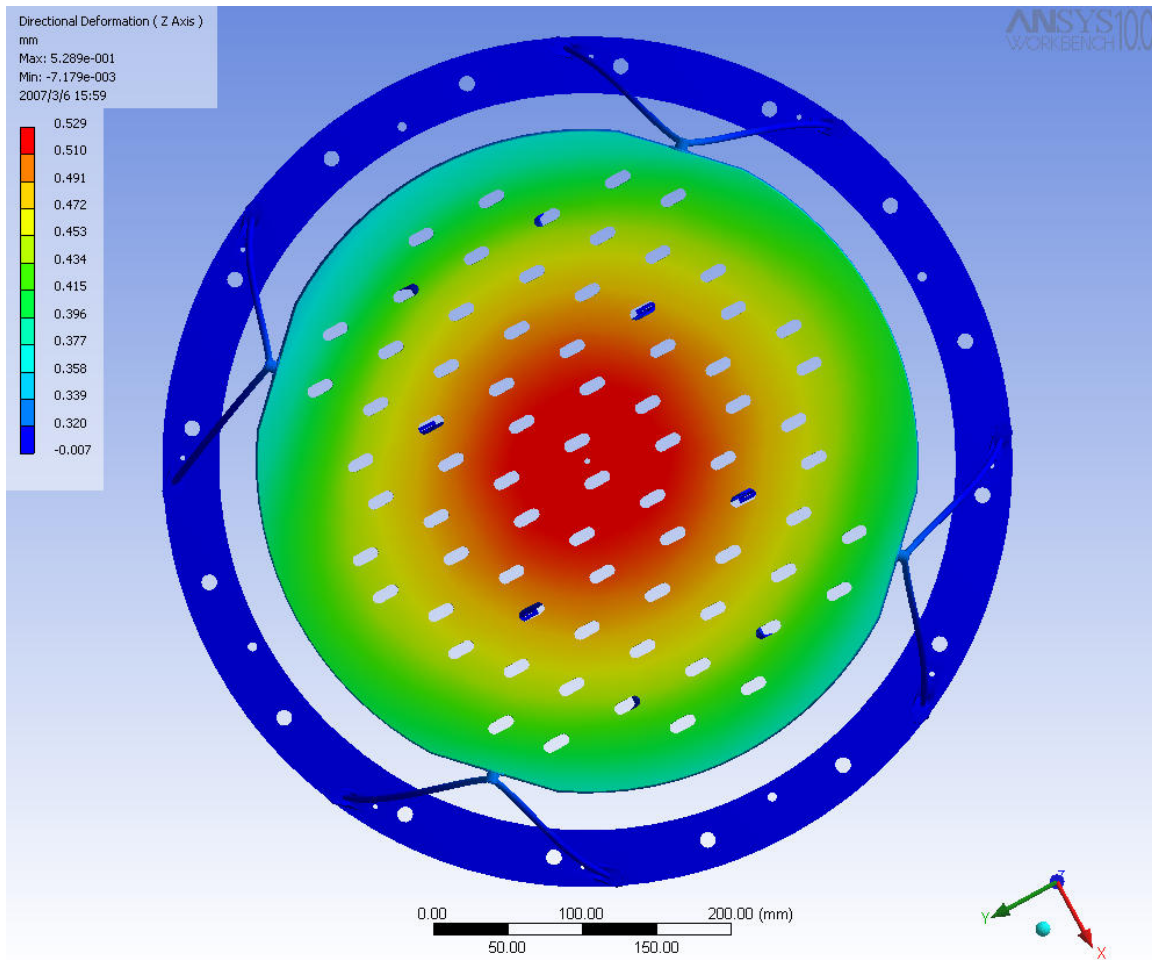


Figure 15 – Deformation in z of Case 2C

4. Conclusions

The deformation of the focal plate is dependent upon many factors but appears to be dominated by the stiffness of the copper braid assemblies and the stiffness of the bipods. As the copper braid assemblies cool down they contract and begin to pull on the focal plate. When the focal plate is simply supported and cannot move to follow the copper braids the deformation of the plate are the largest. In the models where the bipods are included and support the focal plate, the bipods also contract and offer little resistance to the force applied to the focal plate by the contracting copper braid assemblies.

It should be kept in mind that the modulus of the copper braids is not known and has been simply bounded in this analysis. Tests need to be done on actual copper braids to determine their stiffness and then use this measured value in the calculations.

In order to minimize the flatness of the focal plate the following can be done:

- Not restrain the ends of the copper braid assembly but allow them to float in Z.
- Replace the bipods with a support that is more compliant or which contracts the same amount as the copper braid assemblies.



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