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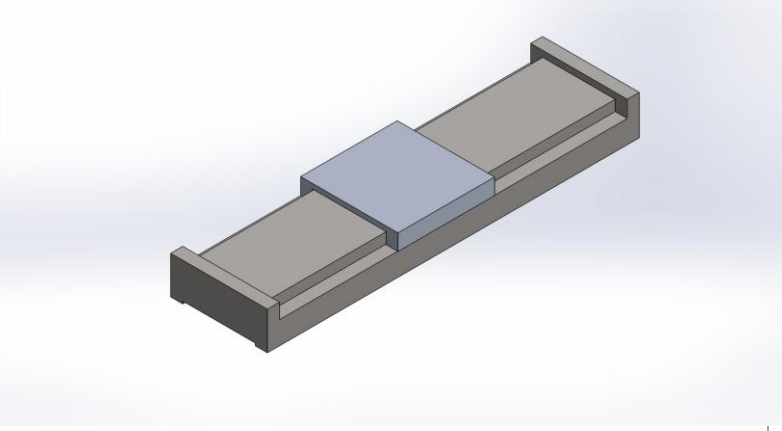
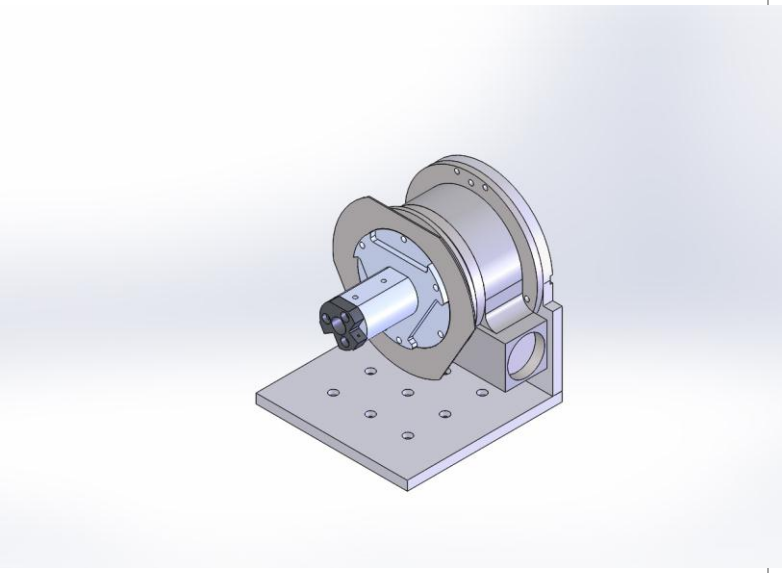


8.3.2 Monochromator Θ_2 Stage Assembly Vibration Analysis

Date: Monday, October 21, 2013
Engineer: Jamie Nasiatka
Analysis type: Frequency



Summary

Beamline 8.3.2 has vibration stability issues that have been affecting sample image quality as imaging resolution has gotten to around 1μm per pixel.

This report summarizes analysis of the vibration modes of the Theta-2 Stage Assembly (both linear and rotational stages) for comparison to physical measurements taken in August of 2013.

It is shown that the Z-Axis stage can be made significantly more rigid by more directly mounting it to the base of the vacuum chamber, and that the rigidity of the rotation stage assembly can be improved by adding a second support gusset and increasing the overall height of the gussets.

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Jamie Nasiatka
10/7/2013

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Description

Beamline 8.3.2 has vibration stability issues that have been affecting sample image quality as imaging resolution has gotten to around 1μm per pixel.

This report summarizes analysis of the vibration modes of the Theta-2 Stage Assembly (both linear and rotational stages) for comparison to physical measurements taken in August of 2013.

The analysis has been broken into two sections – the linear (Z-Axis) stage assembly and the rotational (Θ_2) stage assembly.

In the linear assembly, the initial simulation matches the measured vibration modes in overall direction, but not in frequency. Several scenarios were looked at to determine why. With the rotational assembly, the initial analysis matched the measurements. Design modifications that can increase the overall stiffness of the assembly have also been detailed.

The 'Fixed Blade' scenario is what is nominally installed/as-built, however excess motion at a much lower fundimental frequency is being observed and higher level of motion is being observed. This analysis looks at different methods fo fixturing to determing what may be happening.

For the rotation stage, the analysis correlates with the measured vibrations. Additional analysis looks at stiffening the assembly by adding in a second (downstream) support gusset and varying the overall size of the supports.

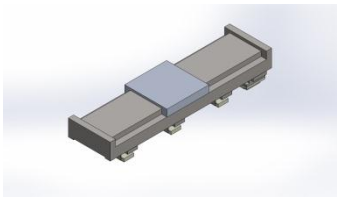
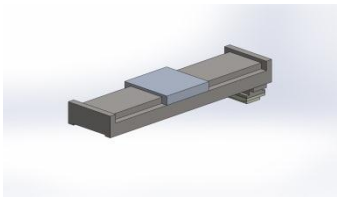
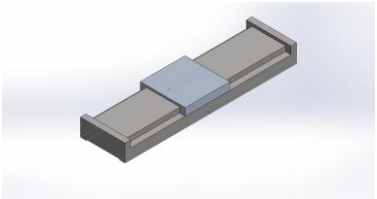
Study Properties – Z-Axis

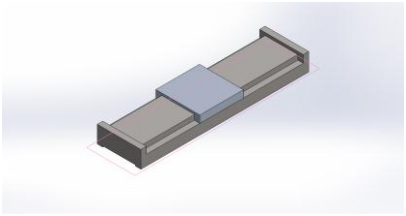
Study name	Z-Axis
Analysis type	Frequency
Mesh type	Solid Mesh
Number of frequencies	5
Solver type	Direct sparse solver
Soft Spring:	Off
Incompatible bonding options	Automatic
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin

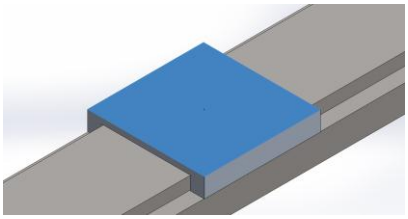
Study Properties – Θ_2

Study name	Theta-2
Analysis type	Frequency
Mesh type	Solid Mesh
Number of frequencies	5
Solver type	Direct sparse solver
Soft Spring:	Off
Incompatible bonding options	Automatic
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin

Loads and Fixtures – Z-Axis

Fixture name	Fixture Image	Fixture Details
Stage With Supports		**Entities:** 4 face(s) – Bottom Faces of Blade Assemblies and Base Block **Type:** Fixed Geometry in Existing Configuration Top and Bottom of Blade Assemblies allowed to slide in horizontal plane in Loose Configuration.
Stage Without Supports		**Entities:** 1 face(s) – Bottom of Base Block. Rest of stage allowed to float **Type:** Fixed Geometry
Fully Fixed Stage		**Entities:** 2 face(s) – Mounting Edges along bottom of stage **Type:** Fixed Geometry

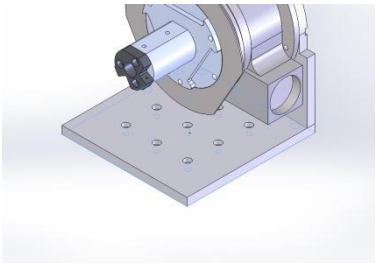
Load name	Load Image	Load Details
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -9.81 **Units:** SI

Remote Load/Mass (Rigid connection)-1		**Entities:** 1 face(s) **Type:** Load/Mass (Rigid connection) **Coordinate System:** Global cartesian coordinates **Force Values:** ---, ---, --- lbf **Moment Values:** ---, ---, --- N·m **Reference coordinates:** 0 250 406 mm **Remote Mass:** 20 kg **Moment of Inertia:** 0,0,0,0,0,0 kg·m^2 **Components transferred:** NA

Comments:
Four scenarios were run with different levels of fixturing. The first analysis was the original design with the base block and all mounting blades fixed to the bottom of the vacuum chamber. The second analysis allowed the blade assemblies to slide in the horizontal plane simulating loose or missing mounting screws. The third analysis removed the blade assemblies allowing the stage to be completely free at the far end. The last analysis looked at the optimal mounting where the stage is rigidly coupled to the vacuum chamber.

The remote mass represents the load on the stage from the rotation stage assembly (including X-Ray optics) and is located at the center of mass of the ⊖2 Assembly.

Loads and Fixtures – ⊖2

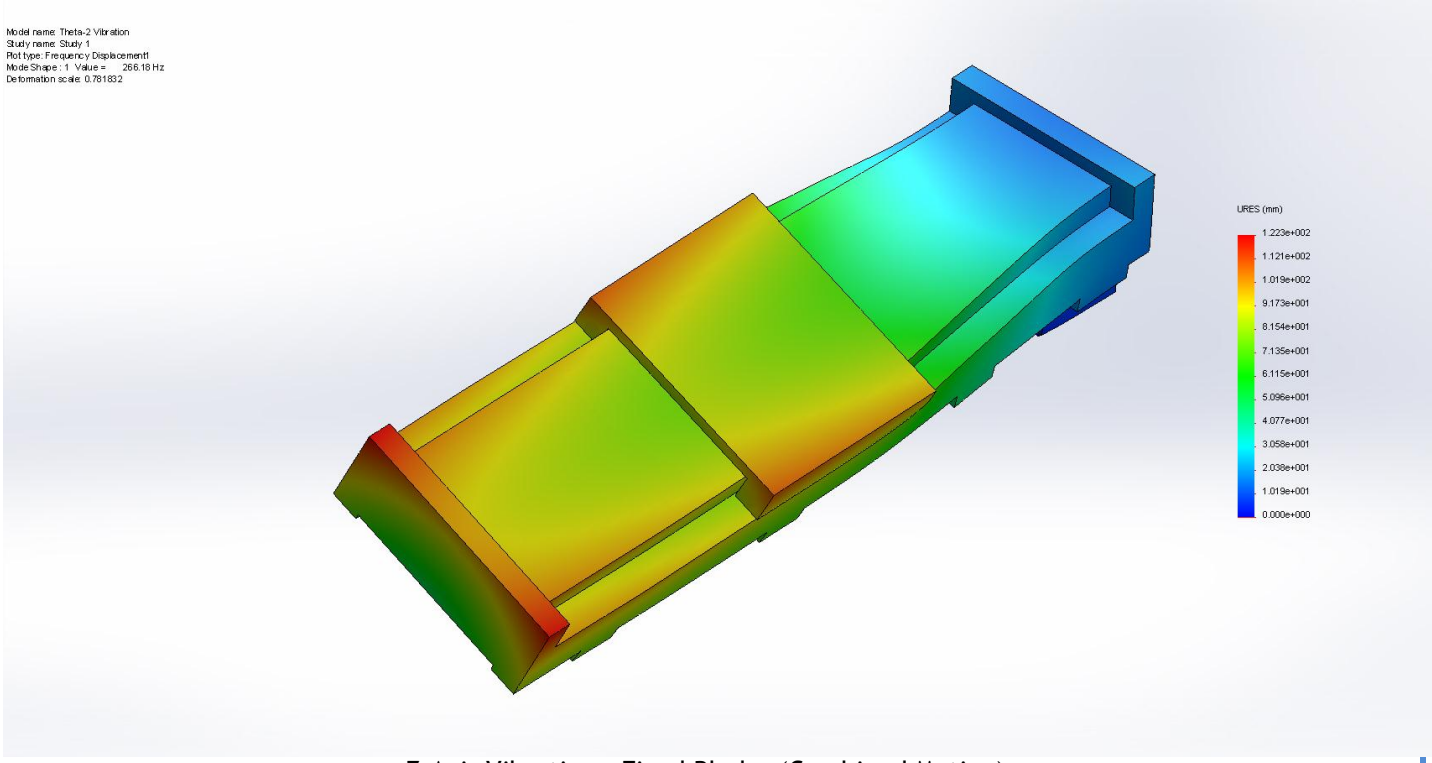
Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) - the bottom of the base of the stage assembly. **Type:** Fixed Geometry

Comments:
The weight of the optics assembly is relatively small compared to the overall mass of the rotation stage and would not affect the overall analysis, and was omitted.

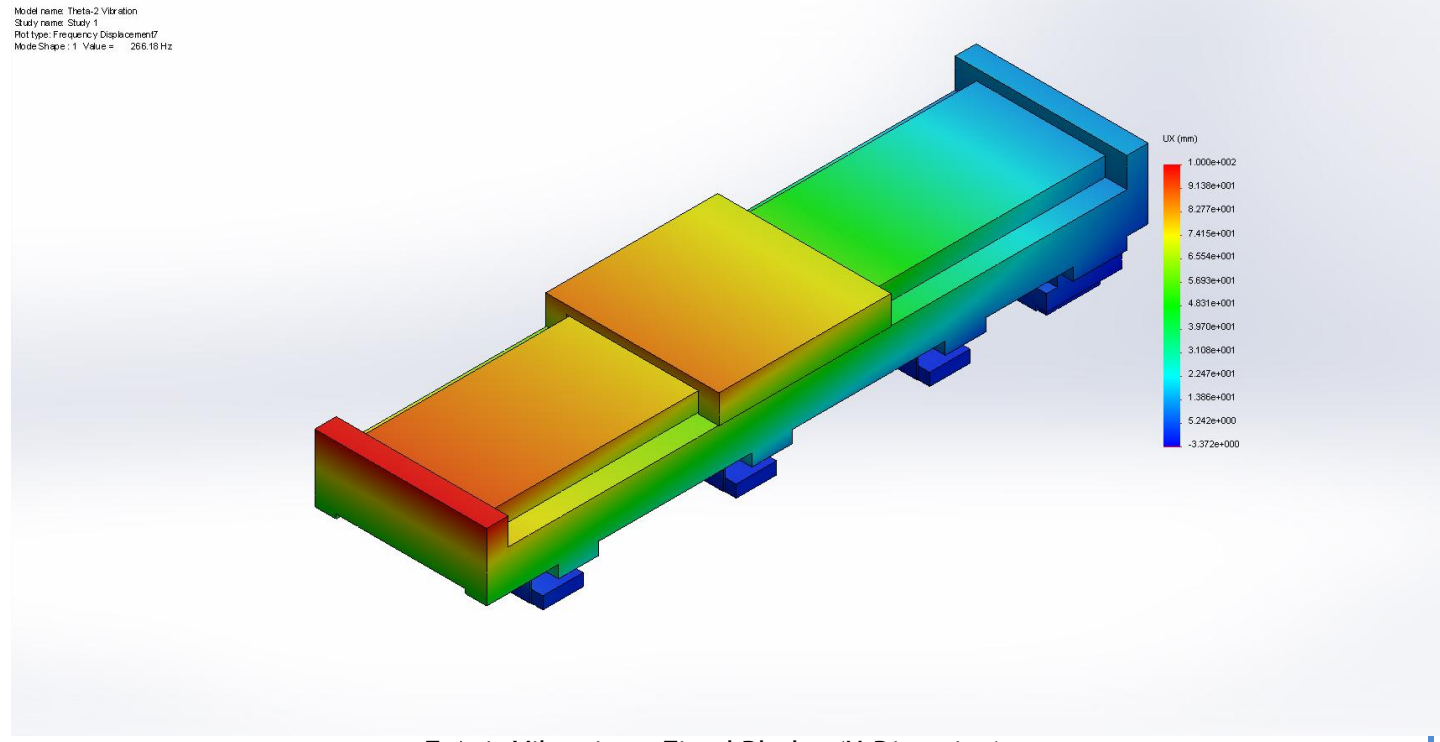
Study Results – Z-Axis

Fixed Blades

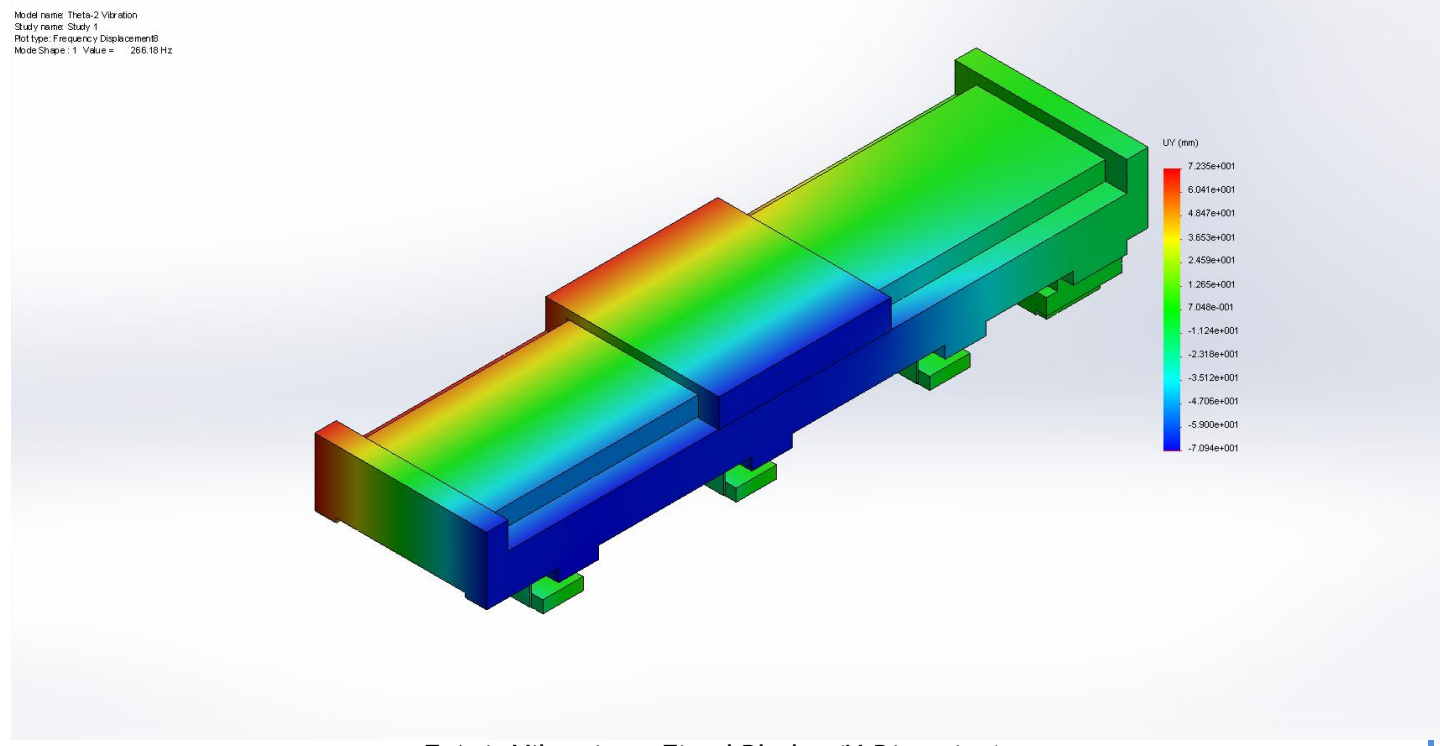
Name	Type	Min	Max
Fixed Blades – Fully Secured to vacuum tank	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 266 Hz)	0 mm	122 mm



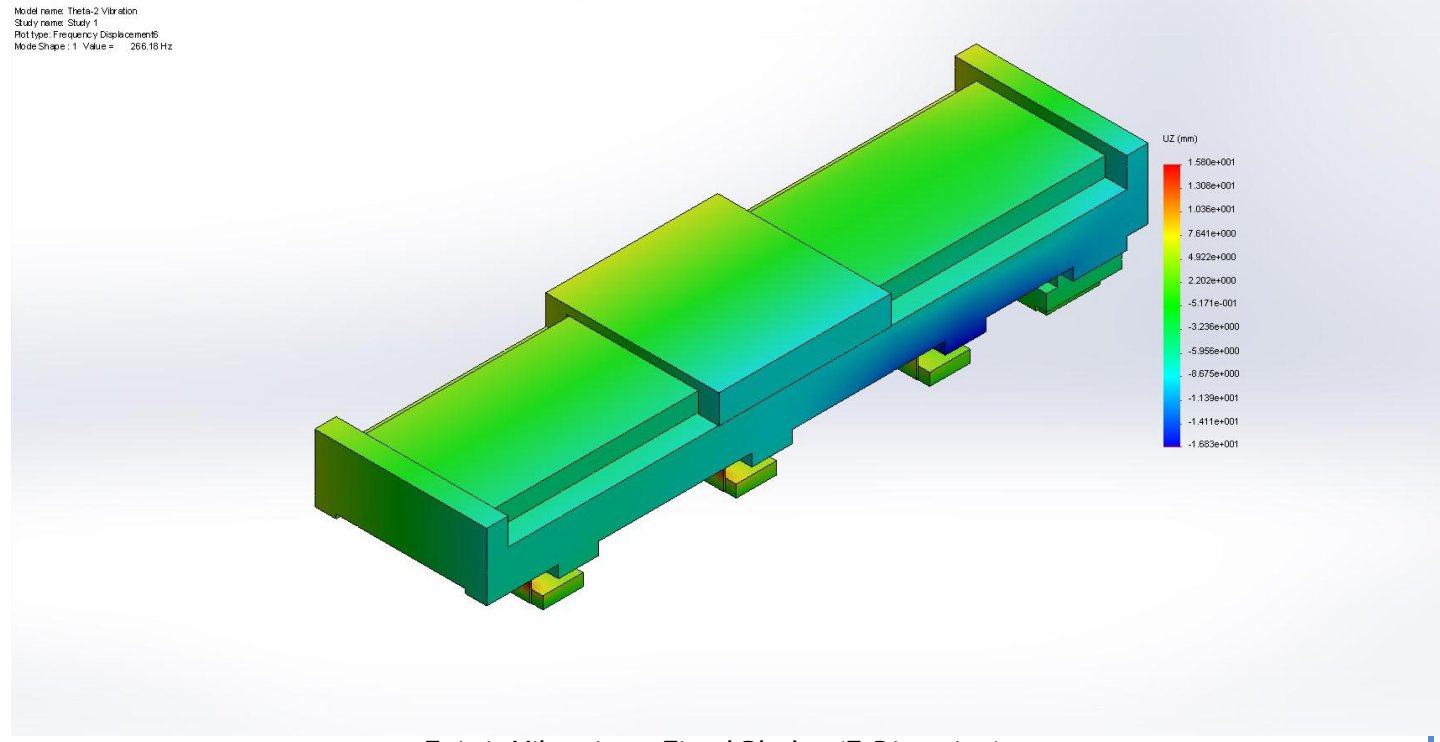
Z-Axis Vibration – Fixed Blades (Combined Motion)



Z-Axis Vibration – Fixed Blades (X-Direction)



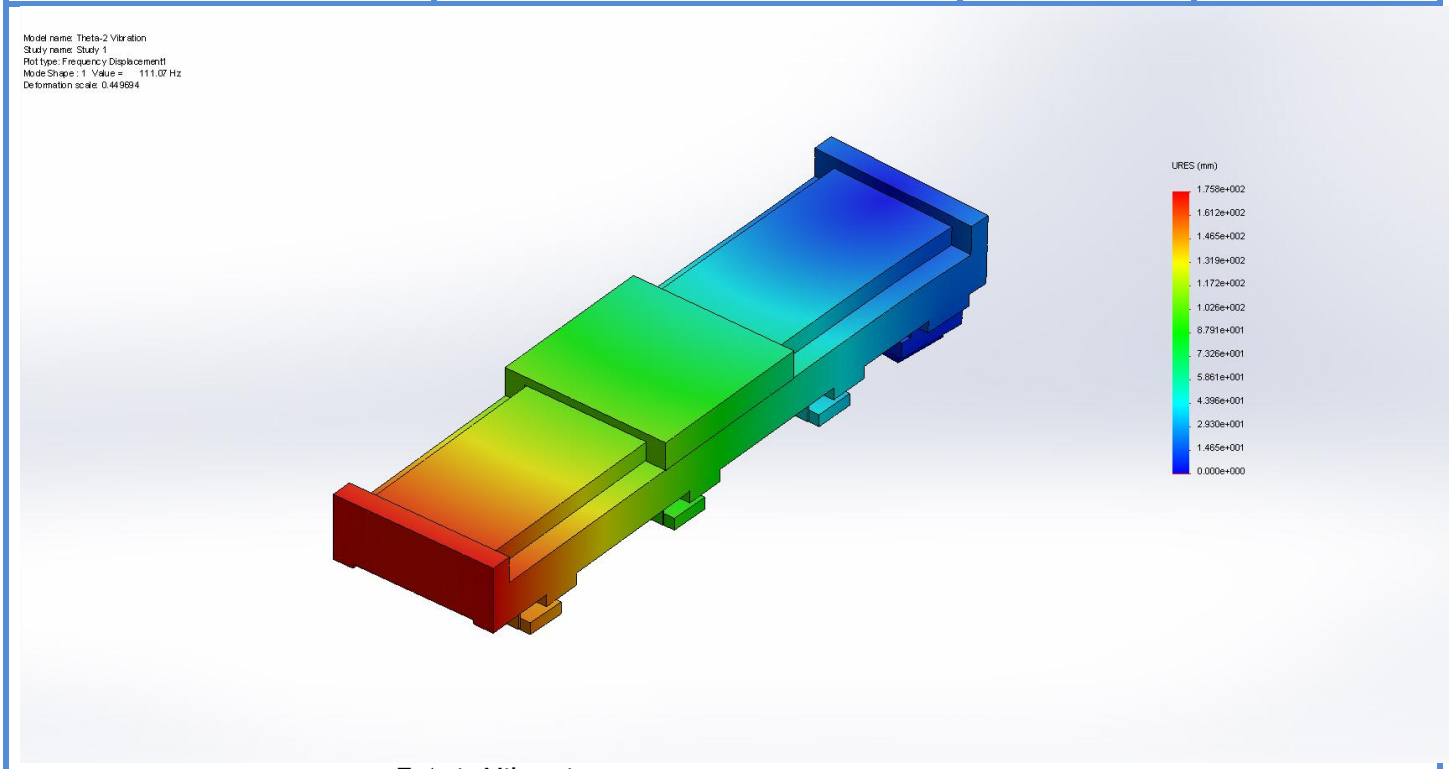
Z-Axis Vibration – Fixed Blades (Y-Direction)



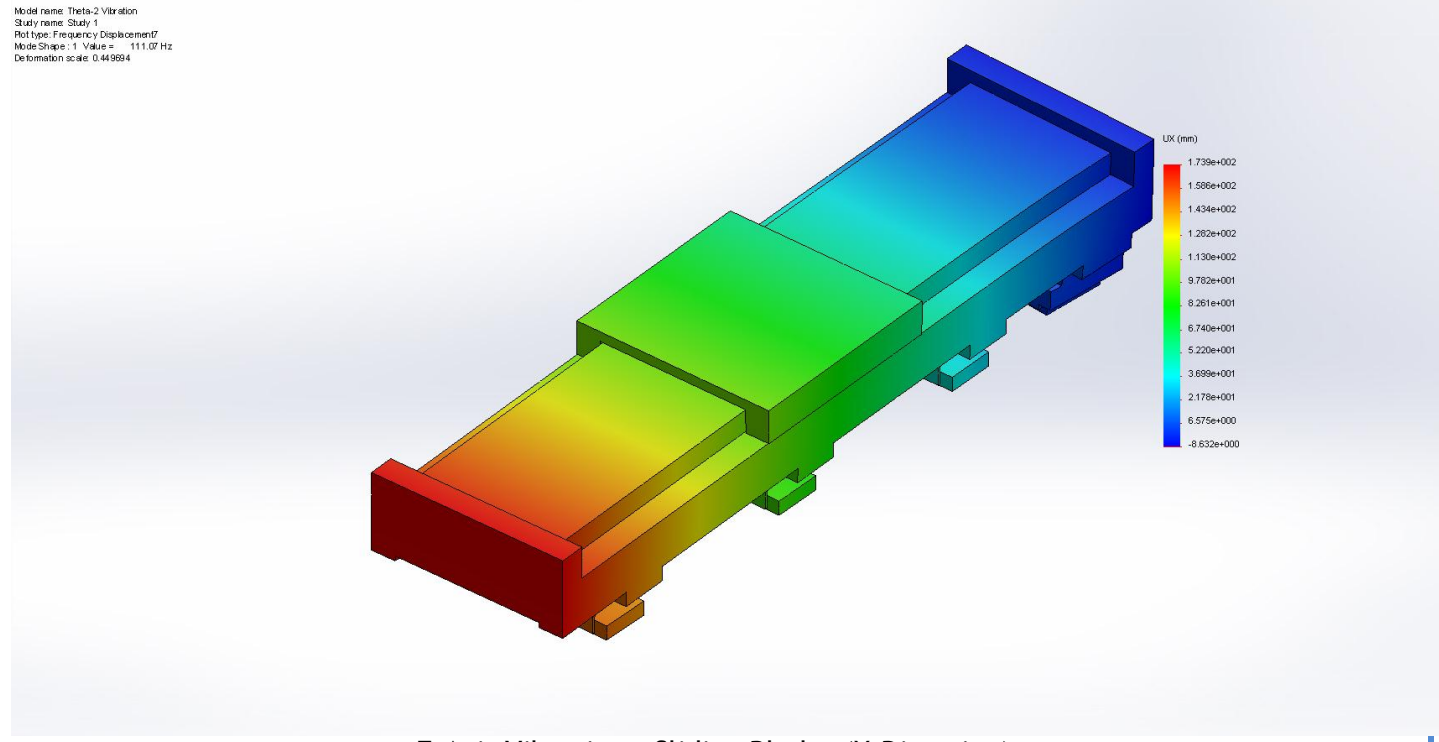
Z-Axis Vibration – Fixed Blades (Z-Direction)

Sliding Blades

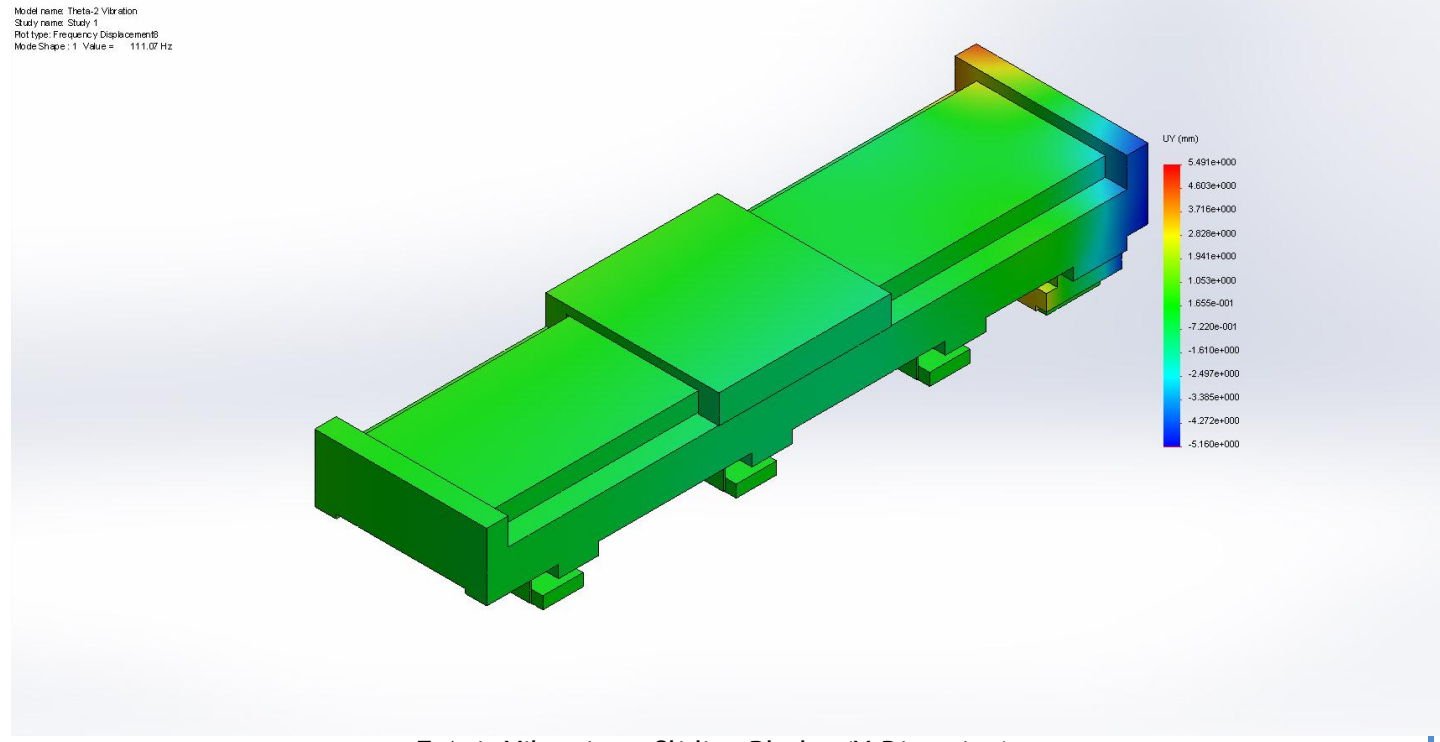
Name	Type	Min	Max
Sliding Blades - Blade assemblies allowed to slide	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 111 Hz)	0 mm	175 mm



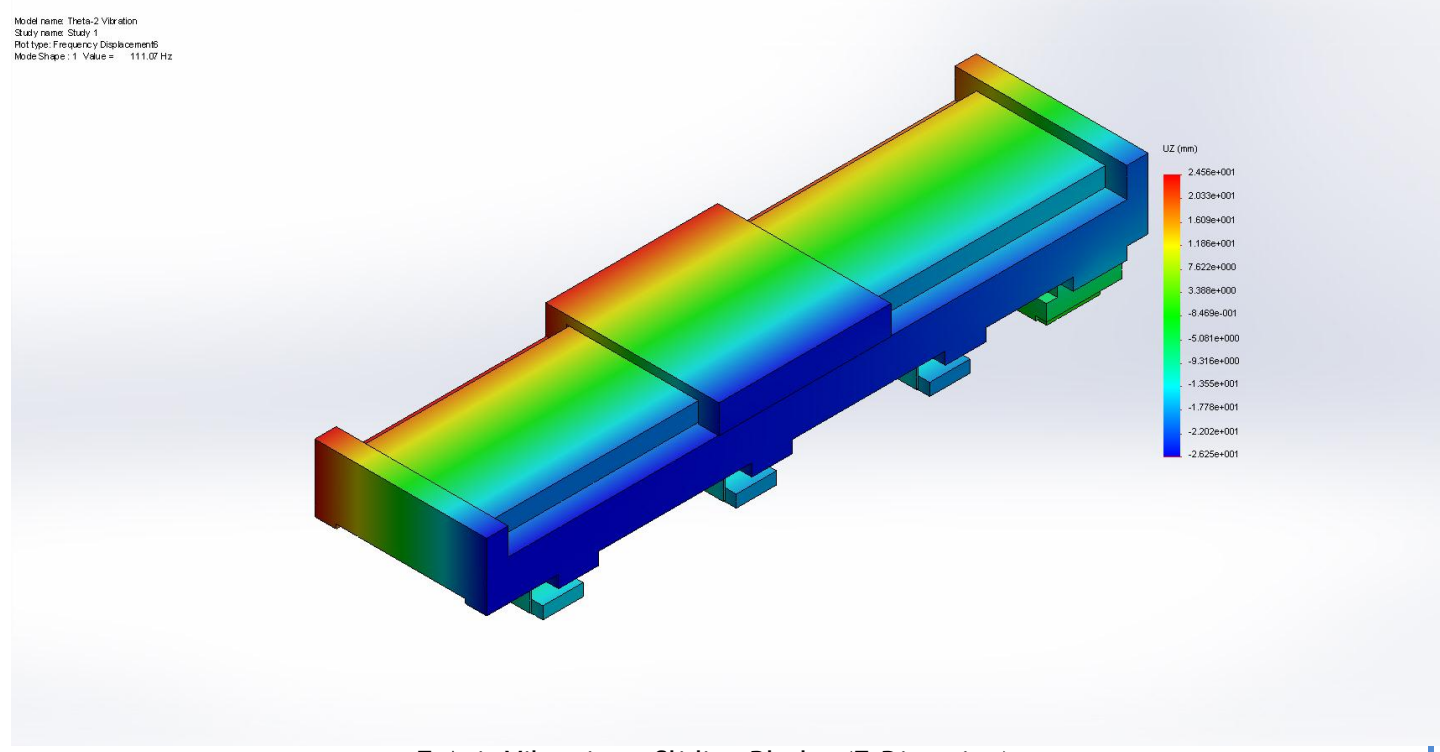
Z-Axis Vibration - Sliding Blades - (Combined Motion)



Z-Axis Vibration – Sliding Blades (X-Direction)



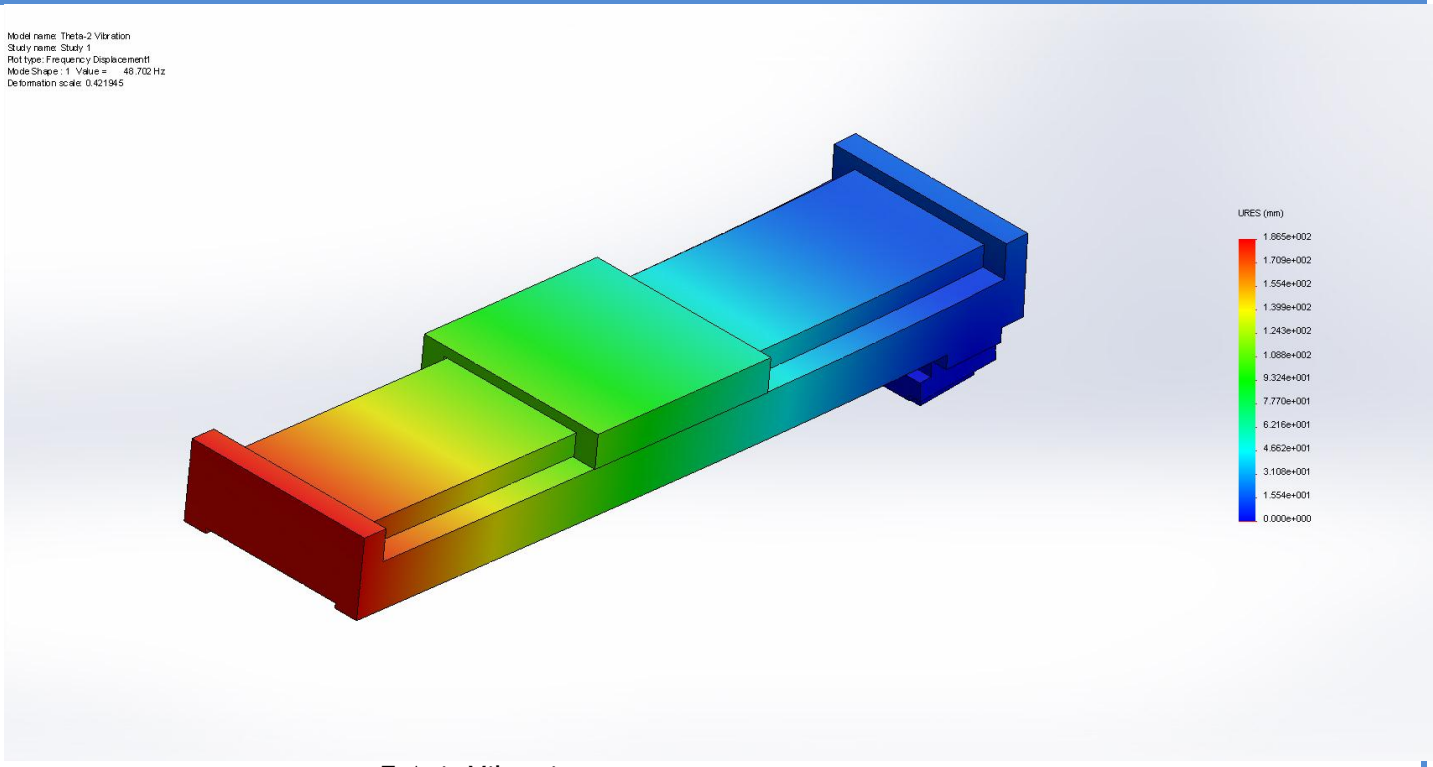
Z-Axis Vibration – Sliding Blades (Y-Direction)



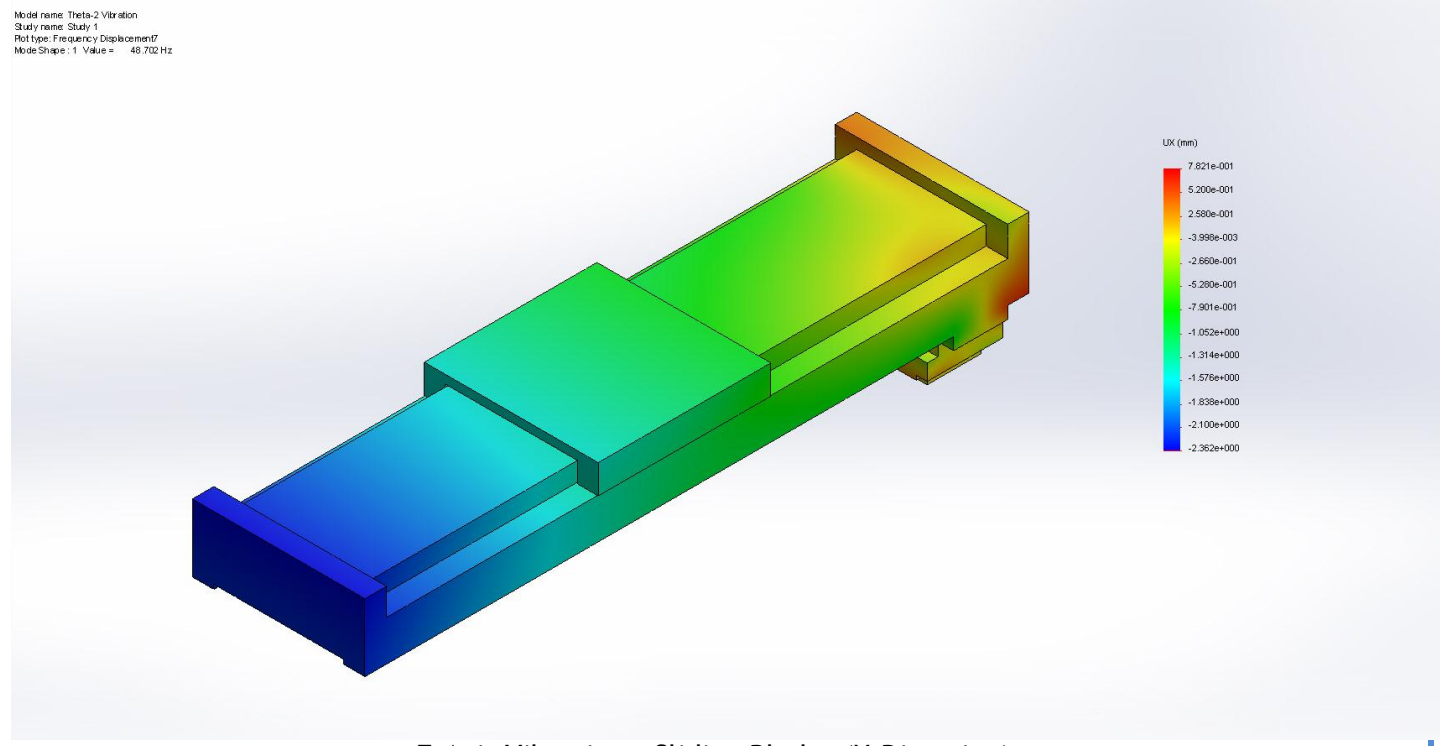
Z-Axis Vibration – Sliding Blades (Z-Direction)

Floating Stage

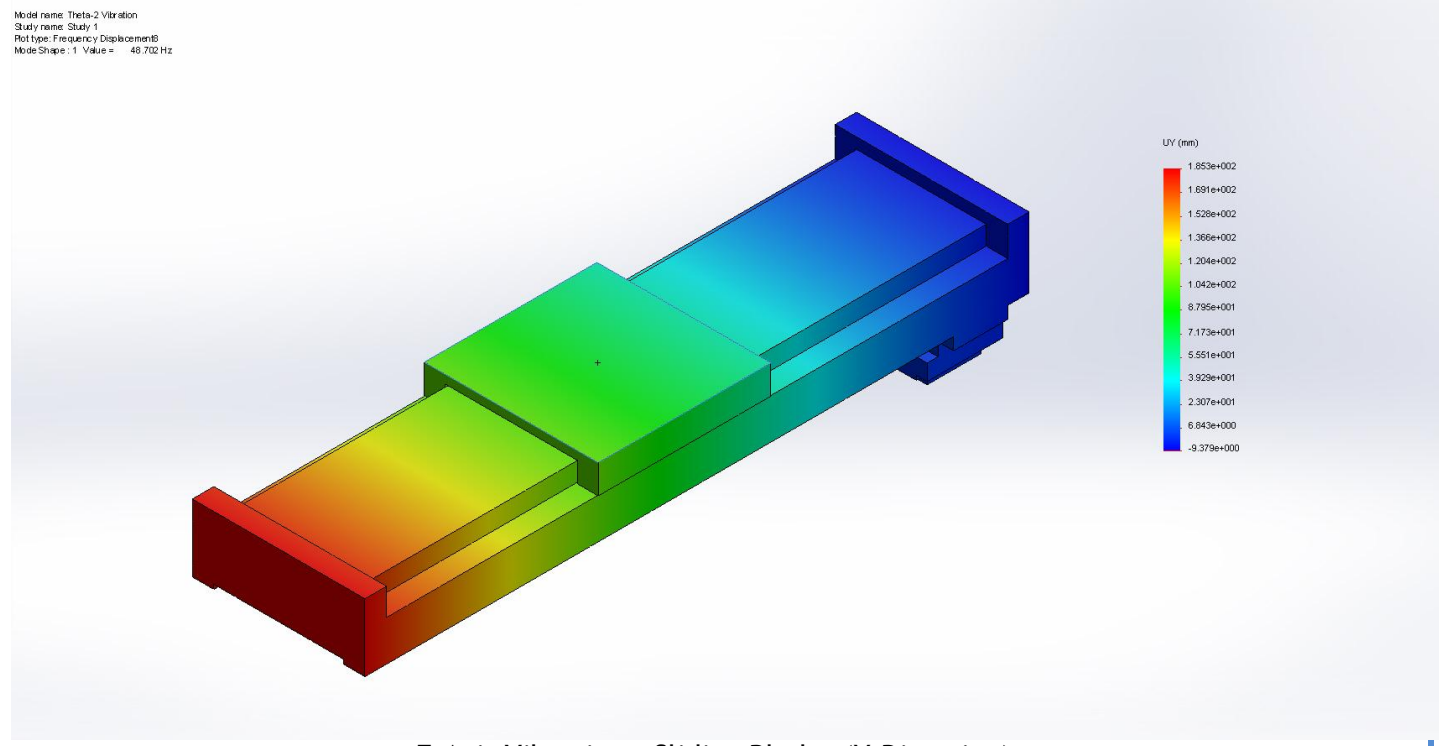
Name	Type	Min	Max
Floating Stage – Blade Supports Removed	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 48 Hz)	0 mm	188 mm



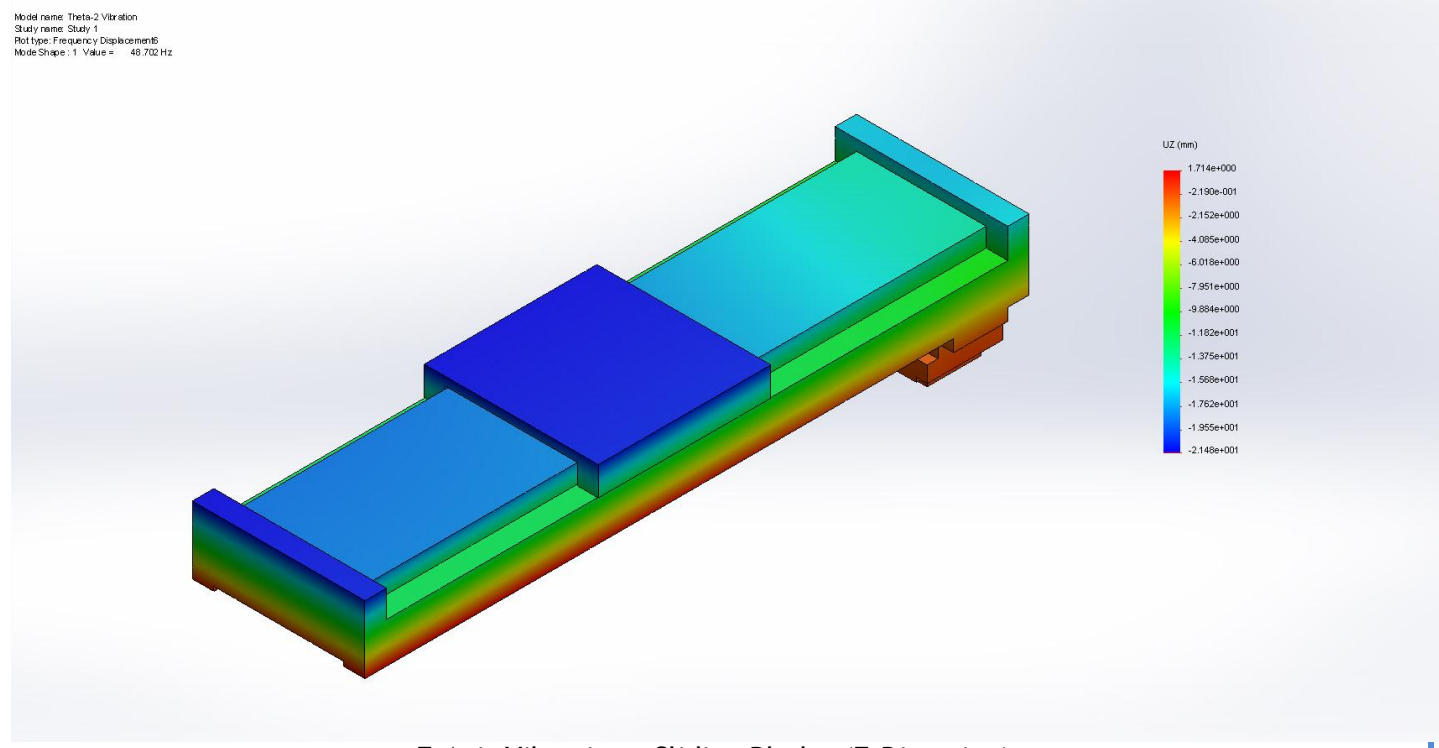
Z-Axis Vibration – Sliding Blades – (Combined Motion)



Z-Axis Vibration – Sliding Blades (X-Direction)



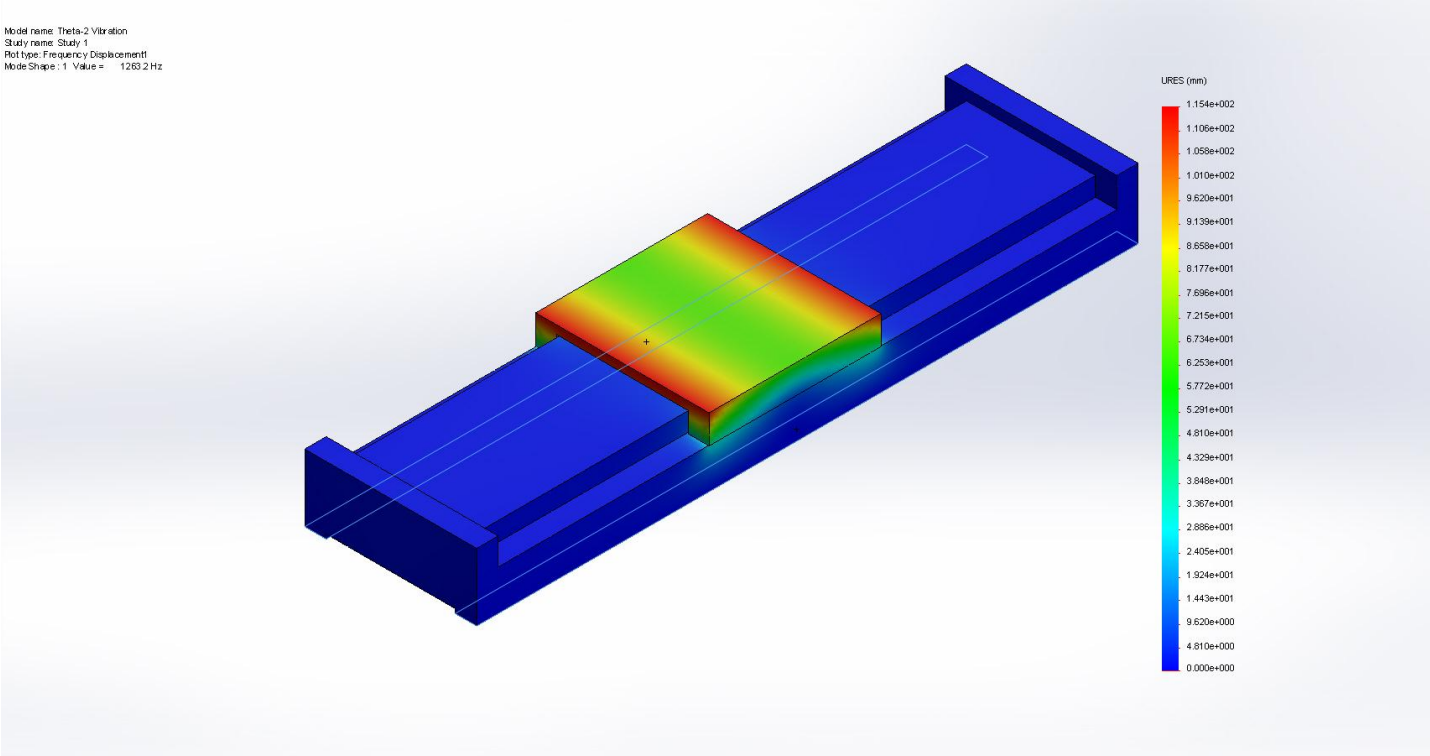
Z-Axis Vibration – Sliding Blades (Y-Direction)



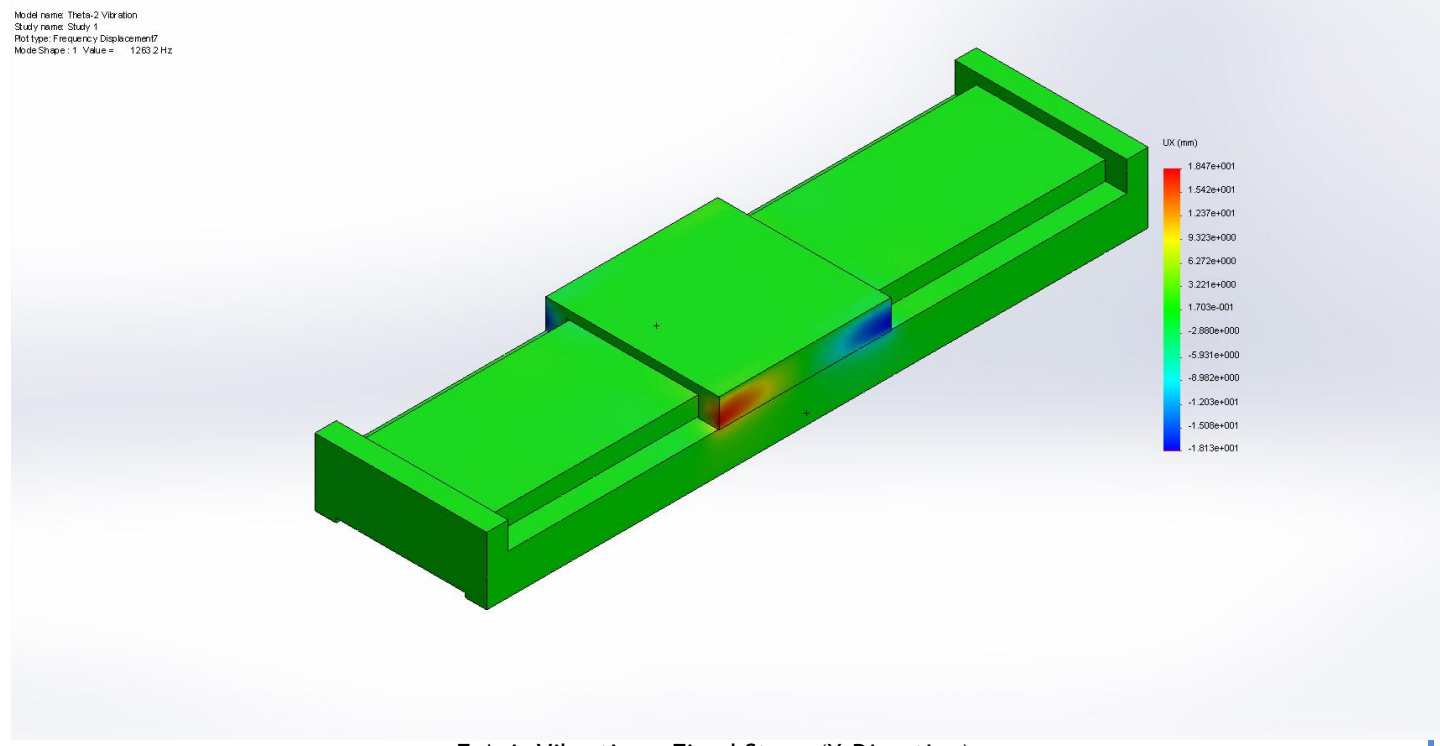
Z-Axis Vibration – Sliding Blades (Z-Direction)

Fixed Stage

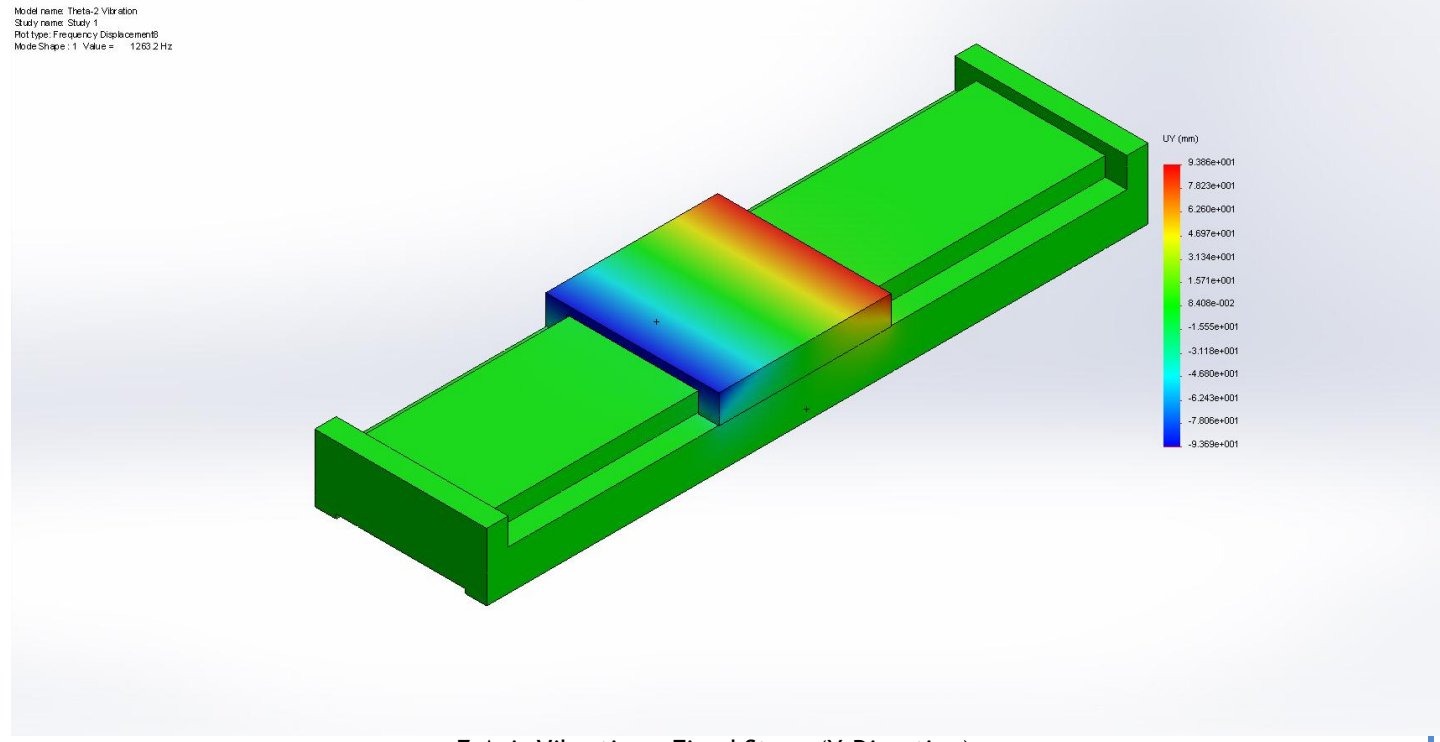
Name	Type	Min	Max
Fixed Stage – Fully secured to vacuum chamber	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 1263 Hz)	0 mm	115.436 mm



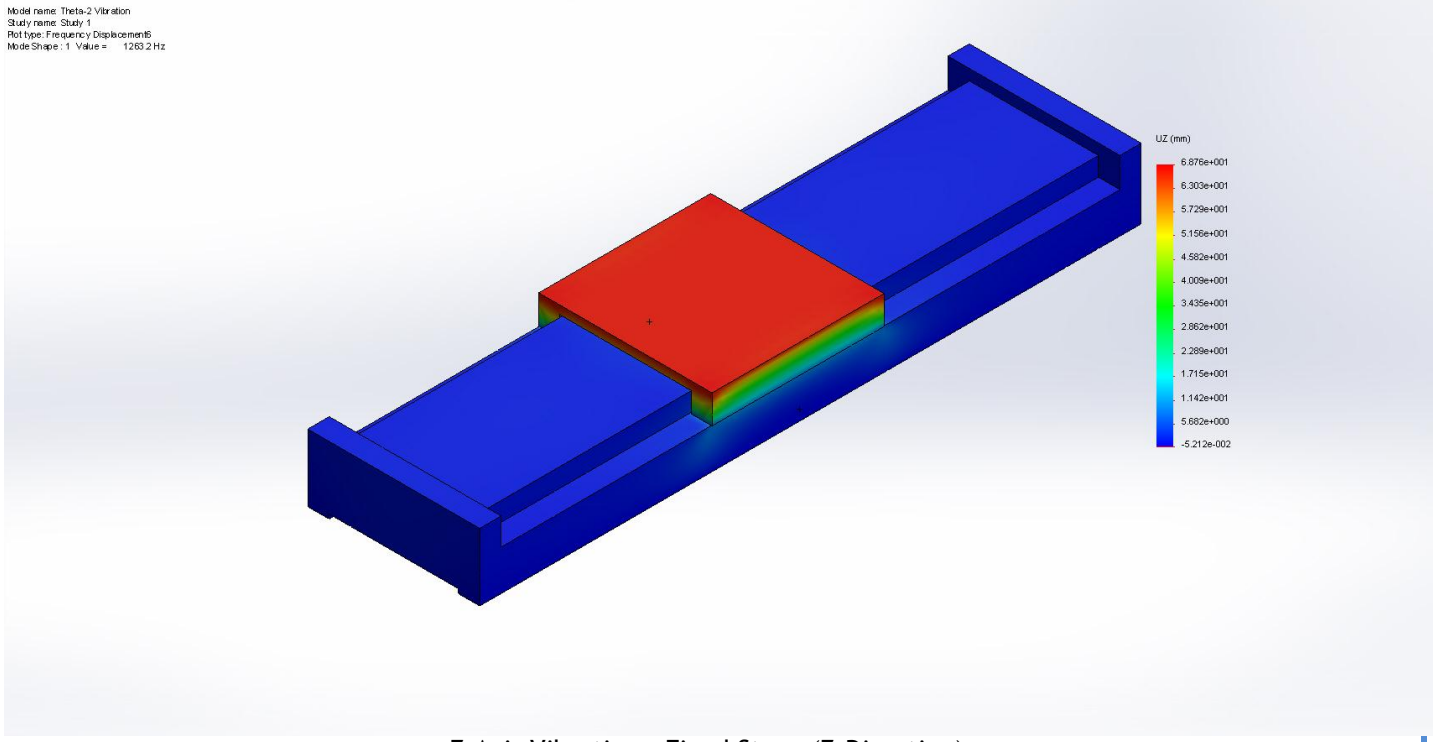
Z-Axis Vibration – Fixed Stage (Combined Motion)



Z-Axis Vibration – Fixed Stage (X-Direction)



Z-Axis Vibration – Fixed Stage (Y-Direction)

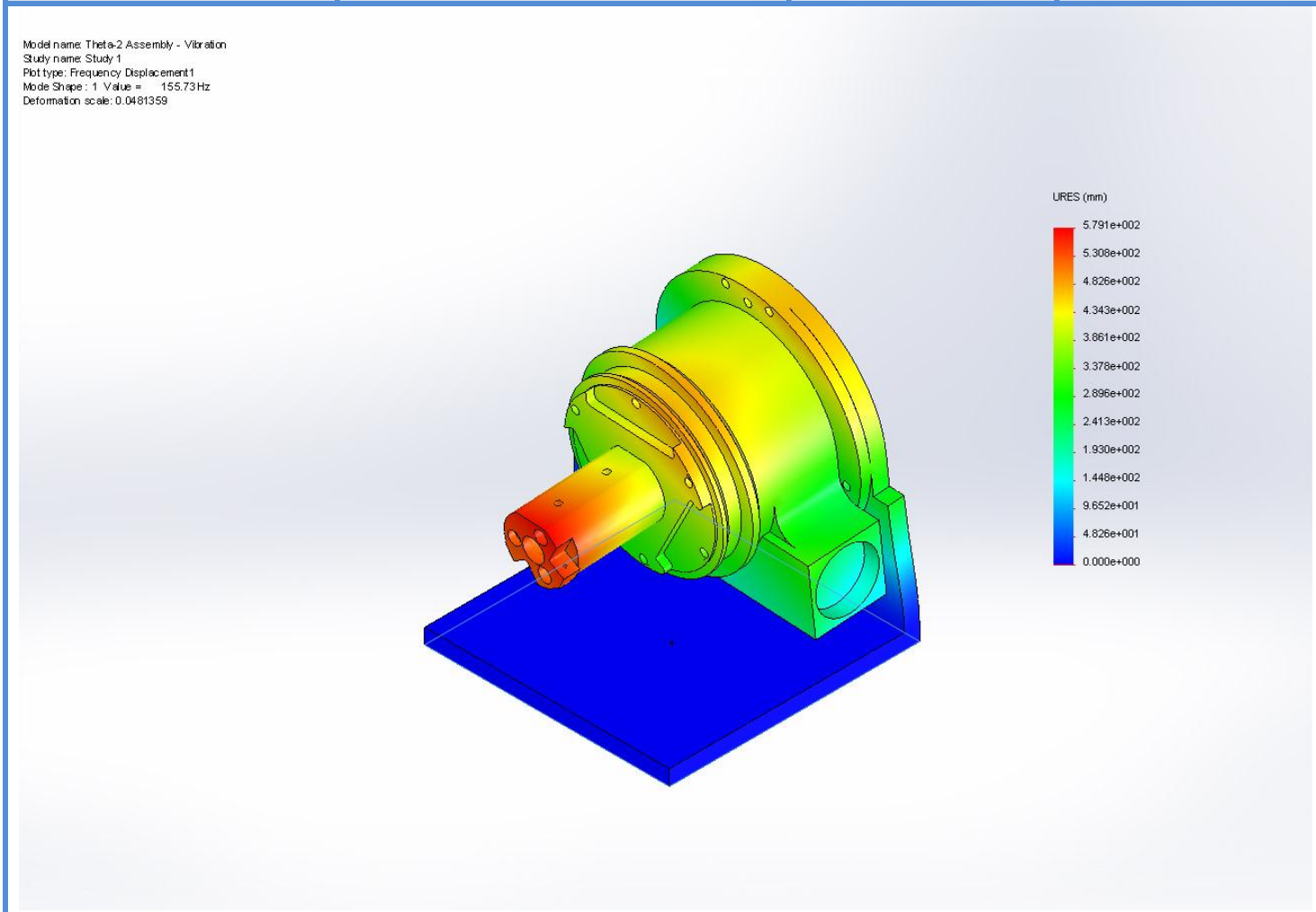


Z-Axis Vibration – Fixed Stage (Z-Direction)

Study Results - Θ2

Current Assembly

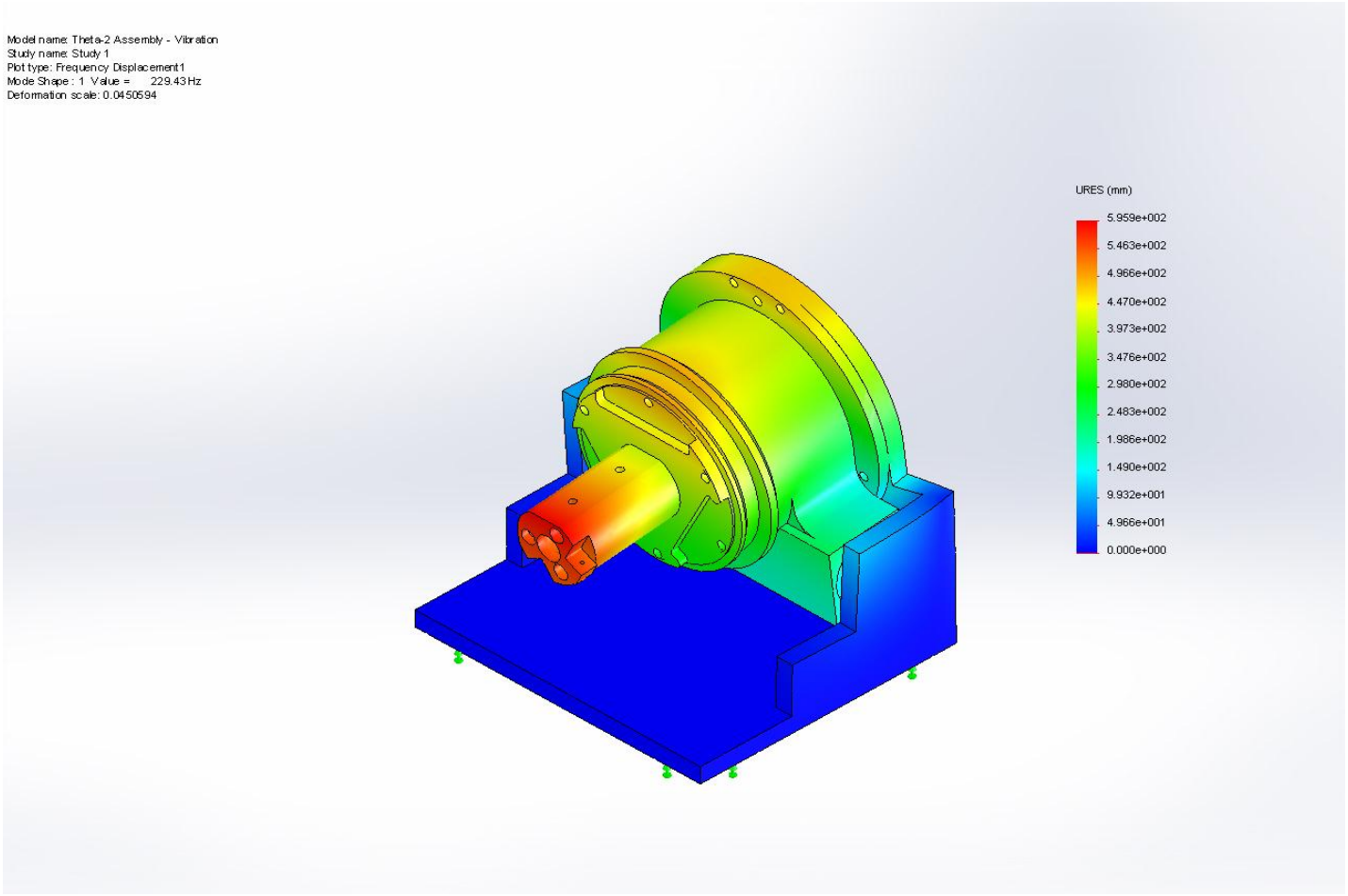
Name	Type	Min	Max
Current Assembly	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 155 Hz)	0 mm	579 mm



Theta-2 Assembly – Current Assembly (Overall Displacement)

2nd Gusset

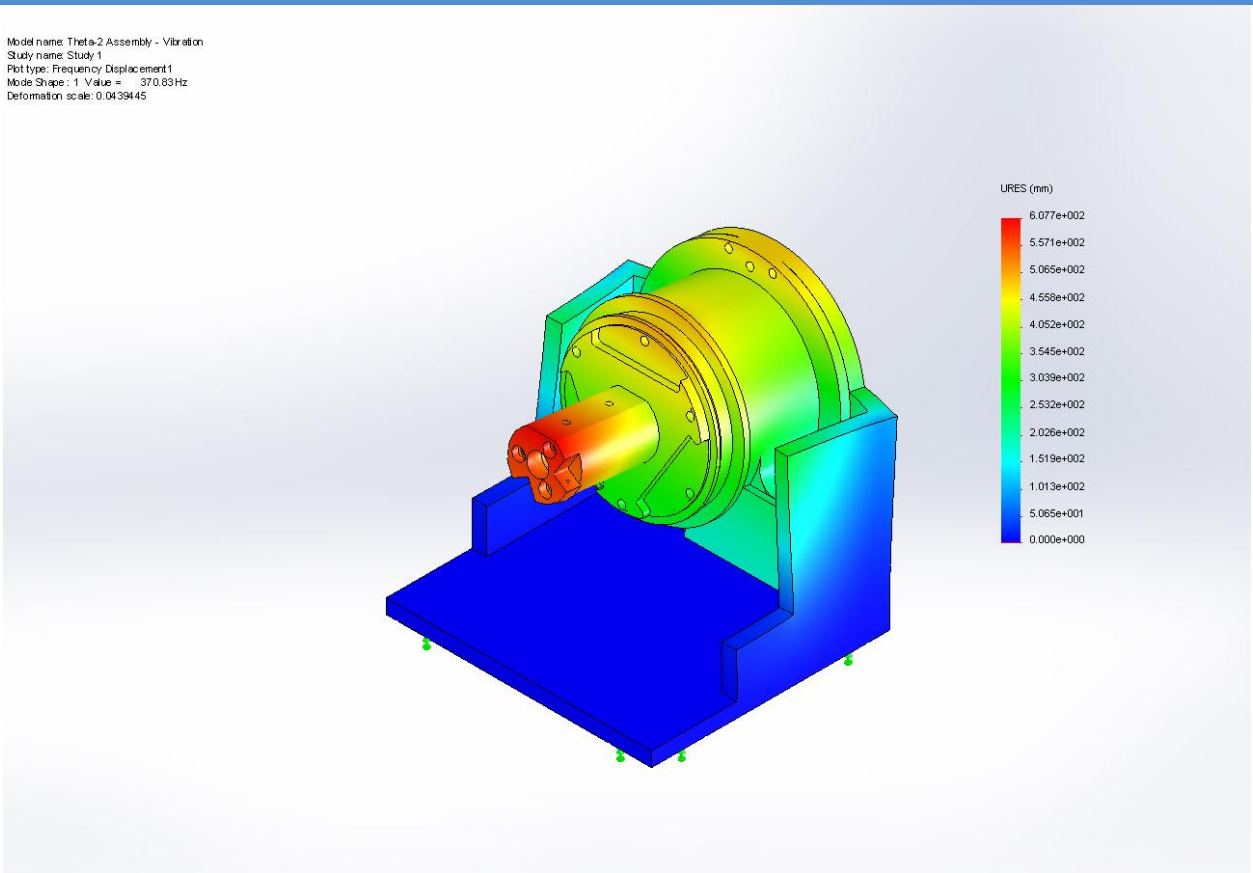
Name	Type	Min	Max
2nd Gusset Added	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 230 Hz)	0 mm	595 mm



Theta-2 Assembly – Current Assembly (Overall Displacement)

Extended Gussets

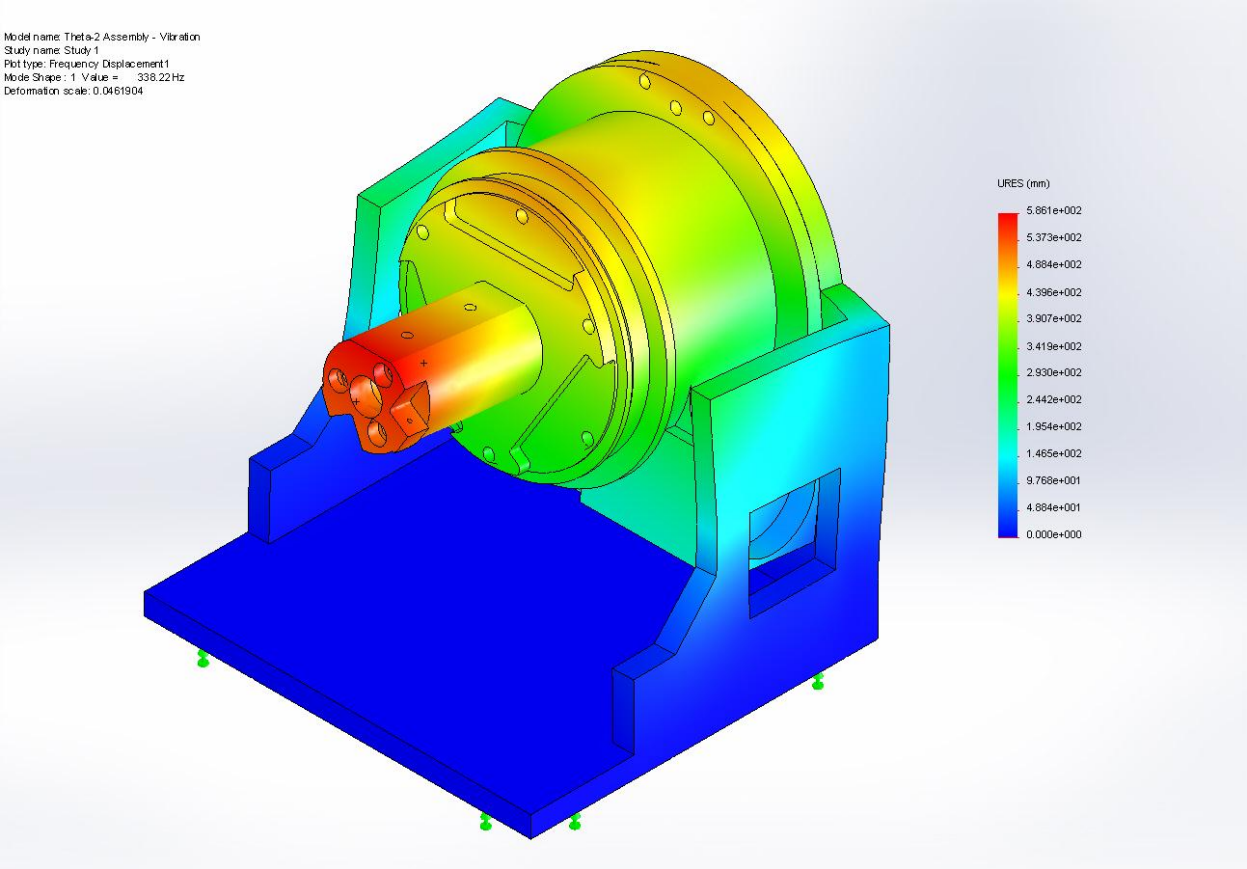
Name	Type	Min	Max
Extended Height Gussets	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 370 Hz)	0 mm	607 mm



Theta-2 Assembly – Current Assembly (Overall Displacement)

Extended Gussets with Motor Clearance

Name	Type	Min	Max
Extended Height Gussets with opening for Stepper Motor	URES: Resultant Displacement Plot for Mode Shape: 1(Value = 340 Hz)	0 mm	586 mm



Theta-2 Assembly – Current Assembly (Overall Displacement)

Conclusion

The Z-Axis stage analysis does not directly match the measured vibrations, however, when the blade supports are allowed to slide in the horizontal plane, and are subsequently removed, the vibrations closely match. This implies that there is something loose on underside of the assembly where it attaches to the vacuum chamber, and the stage is not well coupled. Subsequent analysis of a fully fixed stage shows that the harmonic frequencies go up significantly (1200Hz from 250Hz.)

There would be significant work required to disassemble the stage assembly and investigate the possibility of loose connections (venting the chamber, disassembling both the Θ2 stage assembly and the Z-Axis linear stage, realigning the entire monochromator.) This would increase the base frequency from around 50Hz to around 250Hz.

The same amount of work would be required to replace the mounting blades with a more rigid structure that would give an additional 5x increase in the 1st harmonic frequencies. It is recommended that the entire mounting system be replaced.

For the rotation stage assembly, adding a second gusset and increasing their overall height should increase the 1st harmonic from around 150Hz to ~350Hz. A significant improvement in rigidity. The support structure is easily fabricated, and replacing it at the same time as upgrading the z-axis supports would be a relatively trivial matter.