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BL 8.3.2 Theta-1 Stage Vibration Analysis

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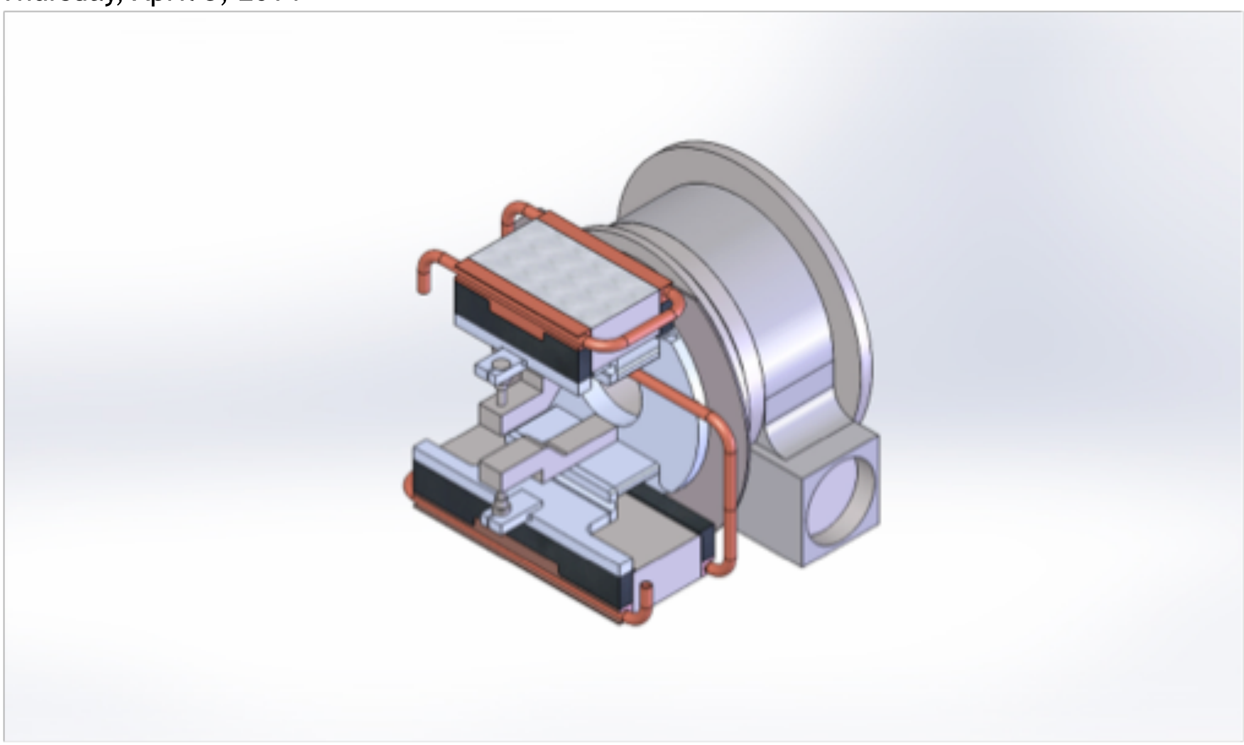

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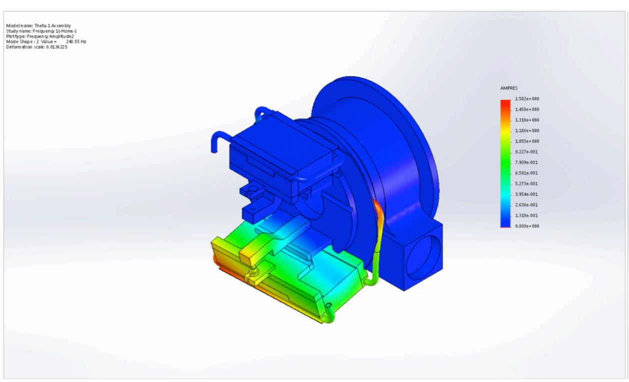
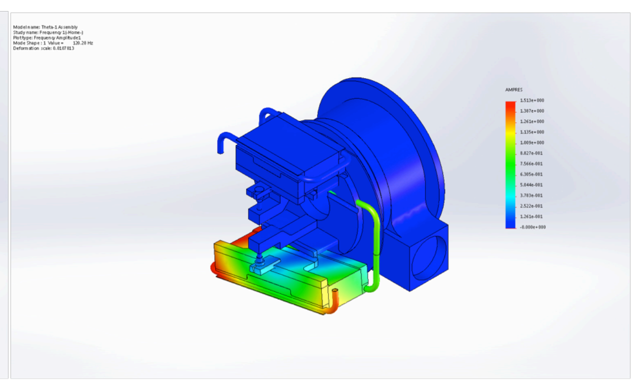
Summary

Beamline 8.3.2 has vibration-related stability issues that have been affecting sample image quality as imaging resolution has gotten to around 1um per pixel. A large amount of the vibration sensitivity has been eliminated, however, there is still significant sensitivity within the Theta-1 assembly that is amplified by water hammer from the monochromators chiller in the 130-165Hz range.

This report summarizes the analysis of the Theta-1 Stage Assembly looking at both harmonic resonances of the system as well as the effect of the water hammer to determine what will make the system more stable.

It is shown that the assembly itself is fairly rigid with a first mode of around 250-300Hz. Flexures for adjusting the roll of the optics were damaged at some point reducing this to around 120-150Hz. Replacing the damaged components should reduce the susceptibility to water hammer. Additionally, it is shown that adding some additional support on the brackets that support the optics will help increase the rigidity a small amount.





Description

Background

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

This report summarizes analysis of the vibration modes of the Theta-1 Assembly along with the effect of water hammer from the monochromator chiller.   Modal Harmonic analysis were conducted on different scenarios to try and determine a ‘weak link’ in the assembly to identify parts that may need redesign.

Analysis Performed

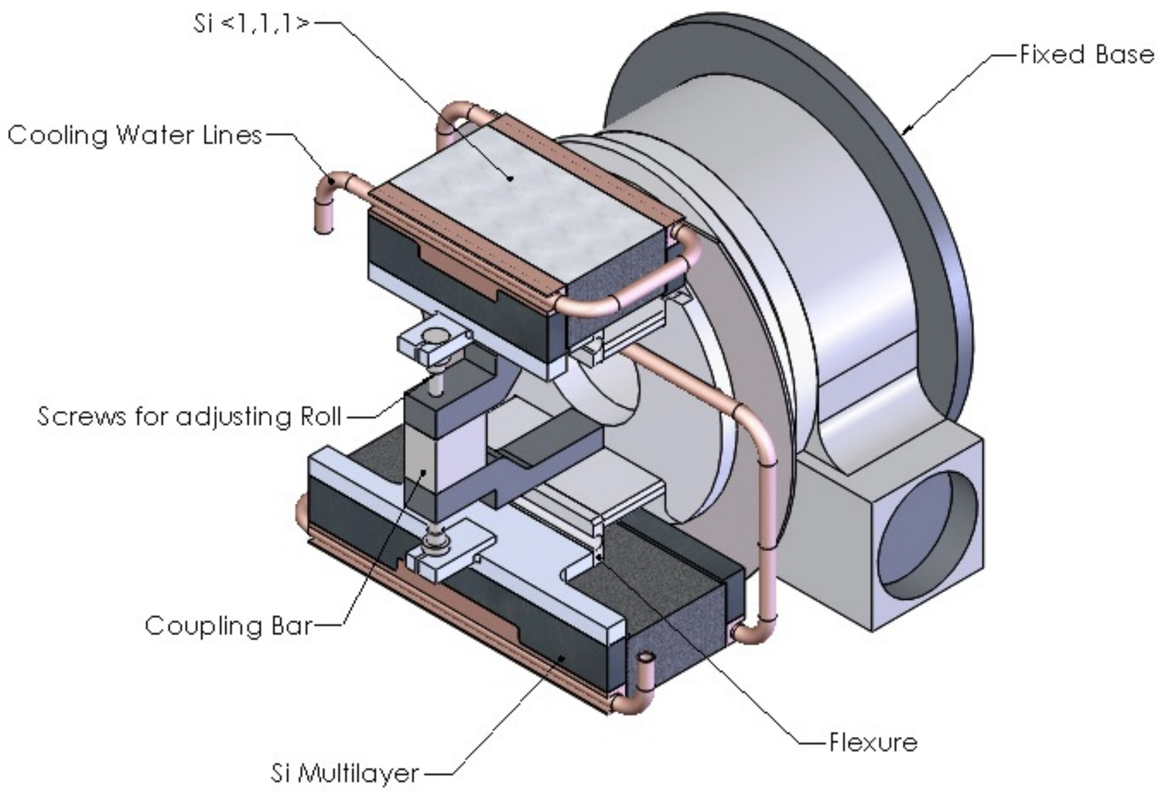
primarily centered around the adjuster/flexures used to change the roll of the optics. Five scenarios were looked at:

- Fixed Adjusters with Flexures
- No Adjusters allowing that end to float freely
- Fixed Adjusters with no Flexures allowing the other end to float
- Fixed Adjusters with Damaged Flexures
- Fixed Adjusters with coupling on the mounting bracket and Flexures

Once the weak links were identified, Harmonic Response analysis were conducted to look at the water hammer effect on the assembly with damaged flexures.

Loads and Fixtures

The back of the stage is fixed to the side of the monochromator and was set to be the fixed reference point. There's no loading for the Modal Harmonic analysis, but for the Harmonic Response analysis an internal water pressure was set to 50psi. This is representative of line pressure at full flow from the chiller.



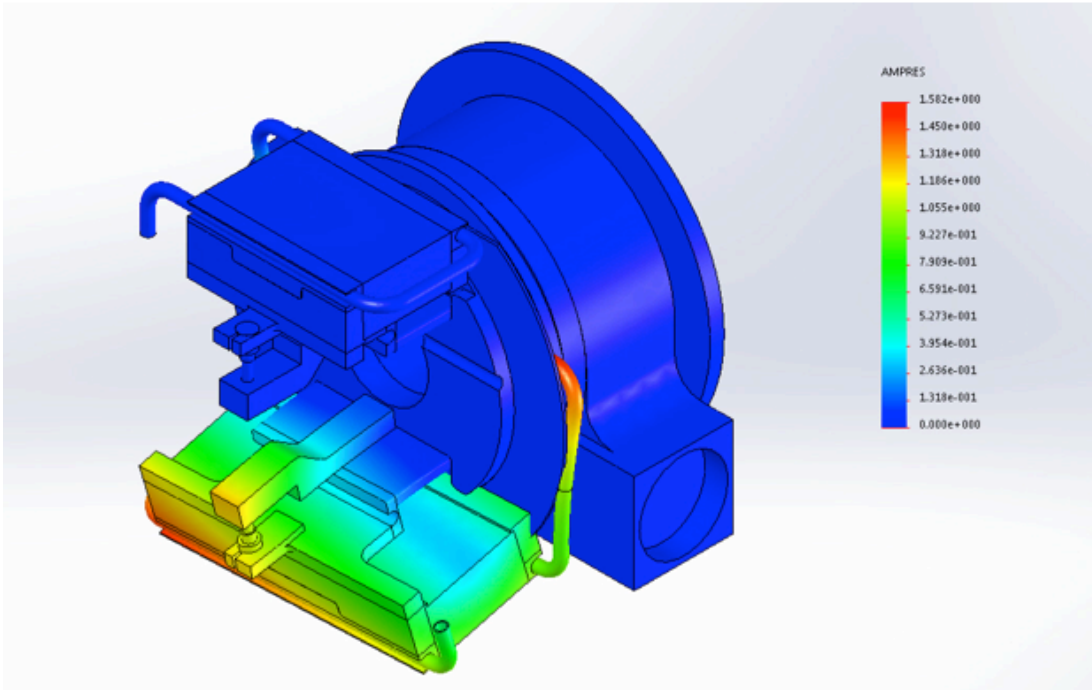
Modal Harmonic Analysis

Fixed Adjusters with Flexures

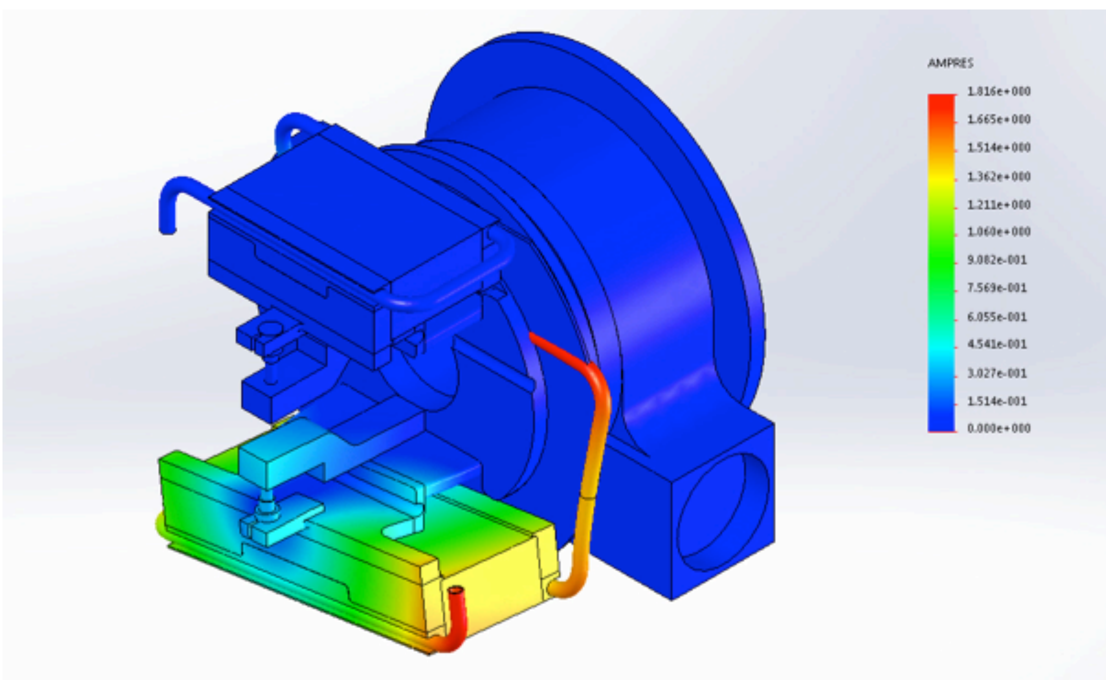
The Multi-layer assembly, Si Xtal assembly, and the cooling lines connecting them all resonated at different frequencies. The table below shows the resonance and general sections of Theta-1 that were affected by them.

The different harmonic resonances were determined to be:

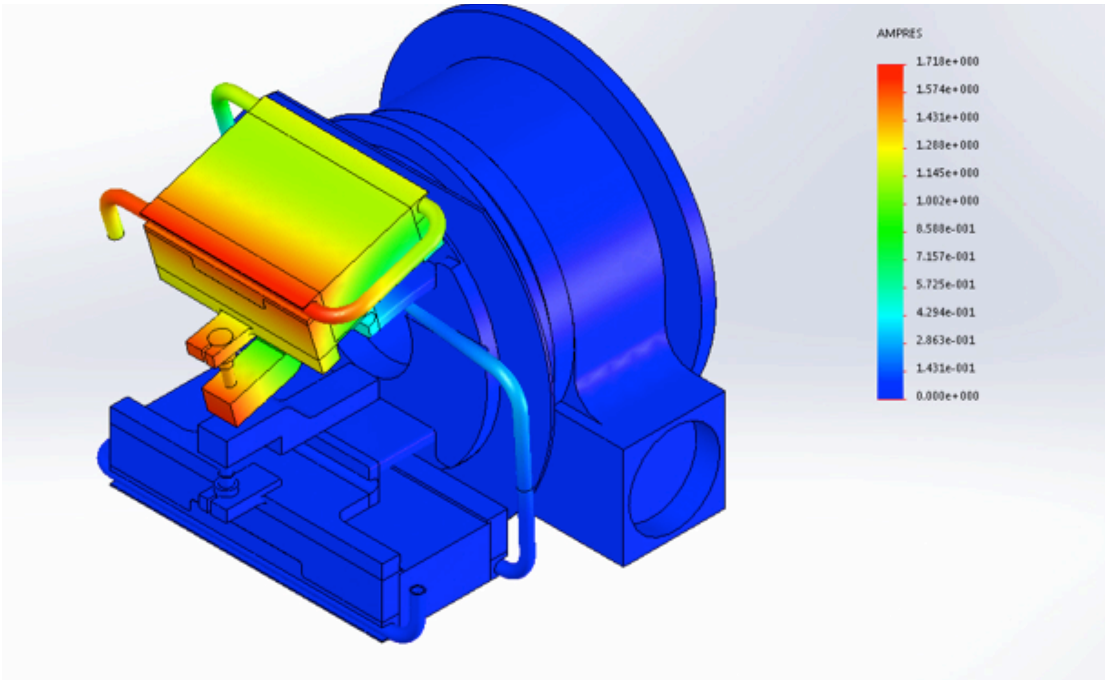
Mode	Frequency (Hz)	Section Affected
1	226 Hz	Cooling Lines and Mulitlayer
2	250 Hz	Multilayer and Cooling Lines
3	260 Hz	Multilayer and Cooling Lines
4	285 Hz	Cooling Lines
5	300 Hz	Si Xtal
6	350 Hz	Cooling Lines
7	410 Hz	Multilayer and Cooling Lines
8	430 Hz	Si Xtal
9	515 Hz	Multilayer and Xtal
10	520 Hz	Multilayer and Xtal



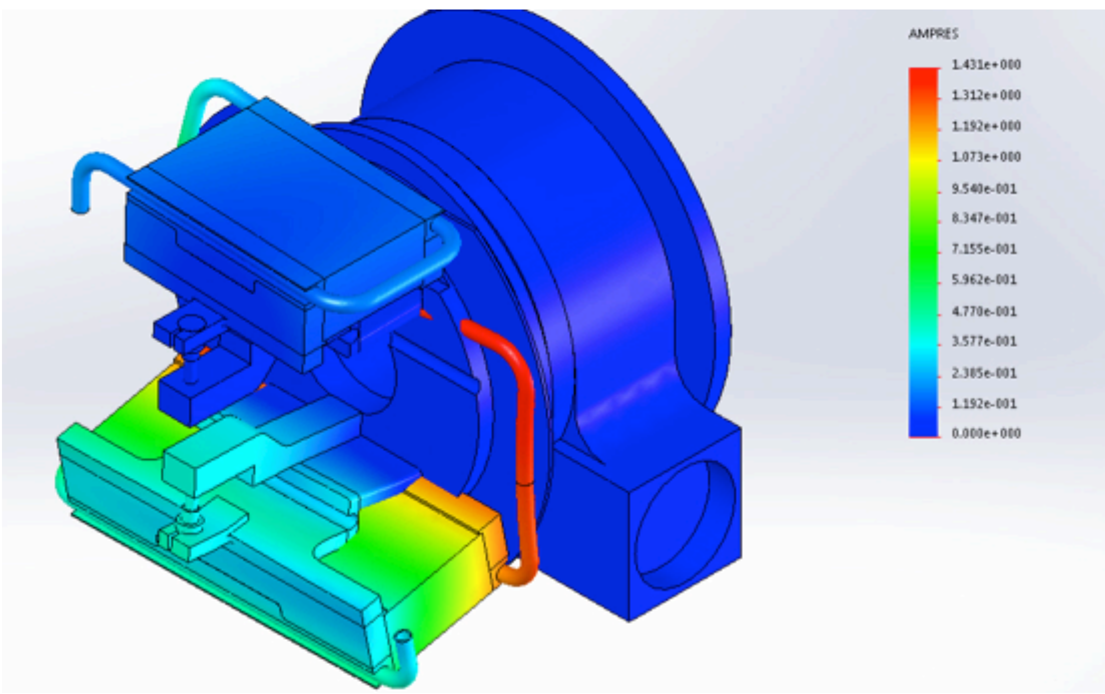
Mode 2 - 250Hz



Mode 3 - 260Hz



Mode 5 - 300Hz



Mode 7 - 410Hz

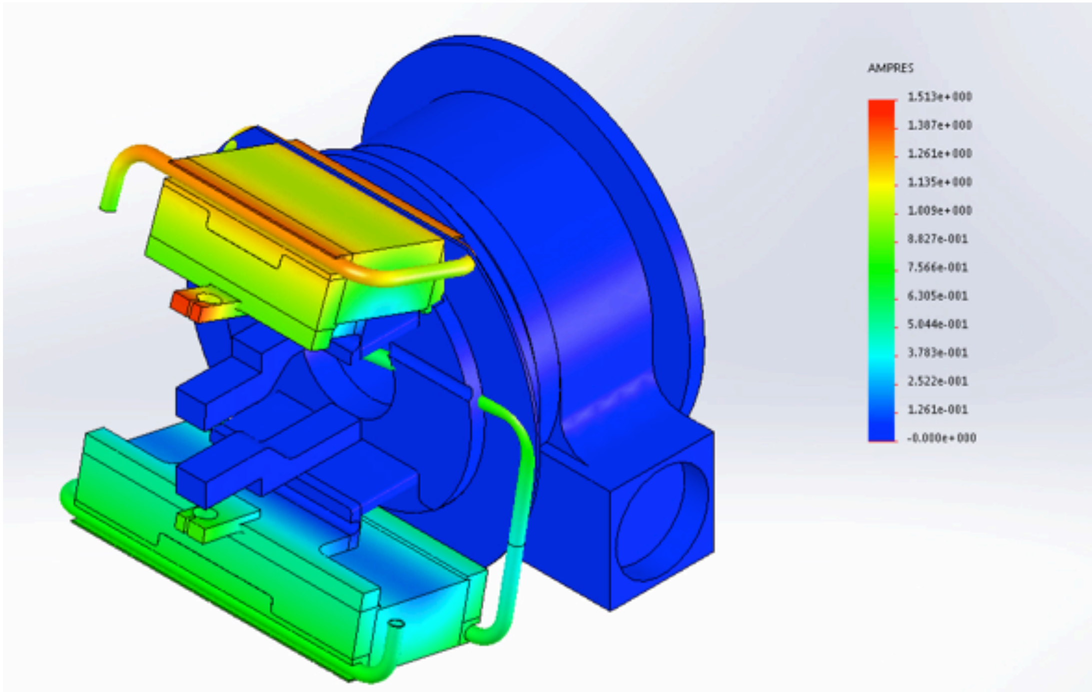
Free Floating (No Adjusters)

Removing the roll adjustment screws and allowing the optics to float freely at the outboard end significantly reduces the lower order modal harmonics to under 100Hz and show that the optics would bounce. 3rd order and above are all higher than 200Hz and out of the problem area.

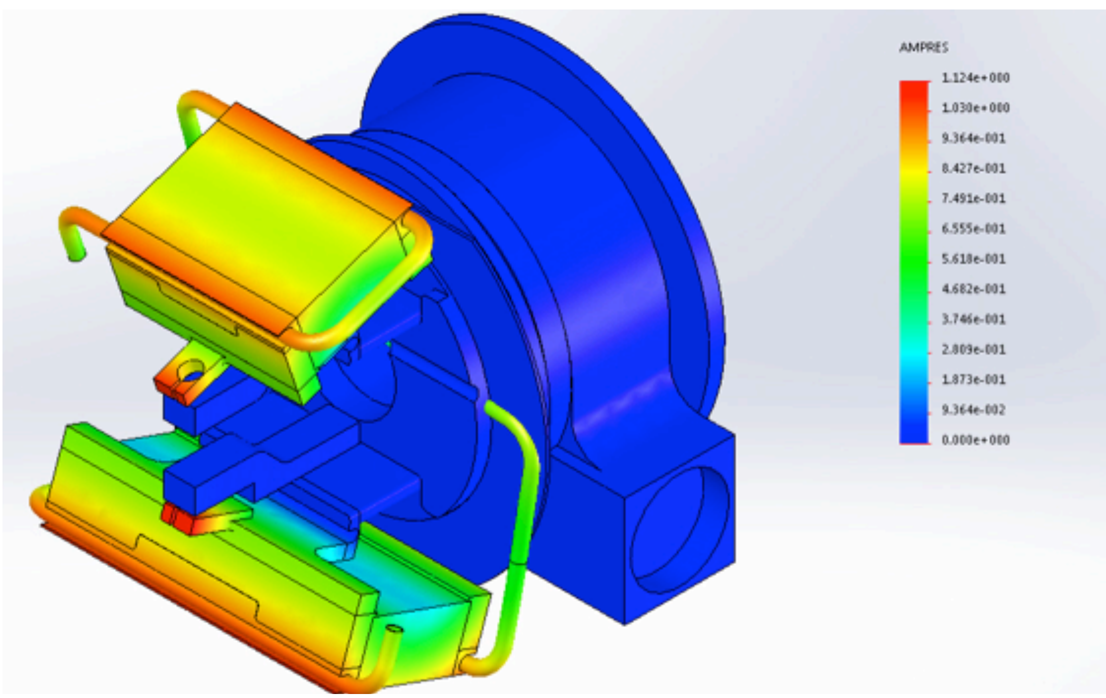
The optical assemblies are held in down at that end by either stiff springs or are clamped. This set of tests shows what could go wrong if they were left free.

The different harmonic resonances were determined to be:

Mode	Frequency (Hz)	Section Affected
1	77 Hz	Multilayer and Si Xtal
2	82 Hz	Multilayer and Si Xtal
3	220 Hz	Cooling Lines
4	240 Hz	Cooling Lines
5	280 Hz	Cooling Lines
6	350 Hz	Cooling Lines
7	365 Hz	Multilayer
8	390 Hz	Si Xtal
9	440 Hz	Si Xtal
10	480 Hz	Multilayer



Mode 1 - 77Hz



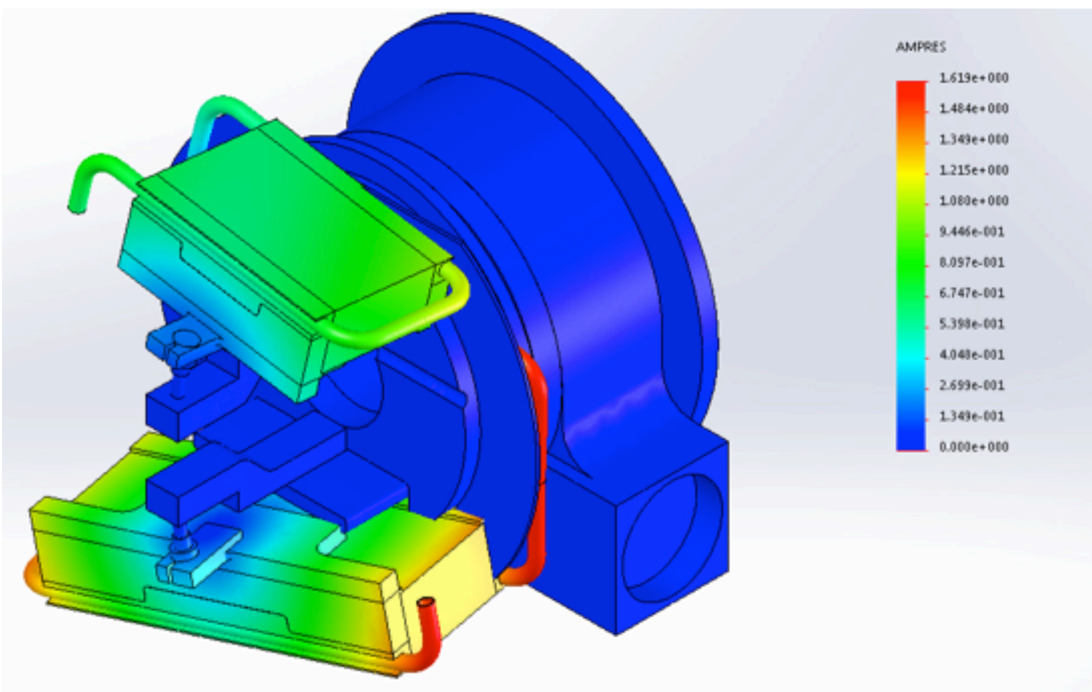
Mode 2 - 82Hz

No Flexures

Completely removing the flexures from the optical assemblies is not a real world possibility as the adjuster screws have ball ends and everything would fall off, however, it does show what would happen if the flexures completely failed.

The different harmonic resonances were determined to be:

Mode	Frequency (Hz)	Section Affected
1	40 Hz	Multilayer
2	47 Hz	Multilayer and Si Xtal
3	54 Hz	Si Xtal
4	60 Hz	Multilayer and Si Xtal
5	75 Hz	Multilayer and Si Xtal



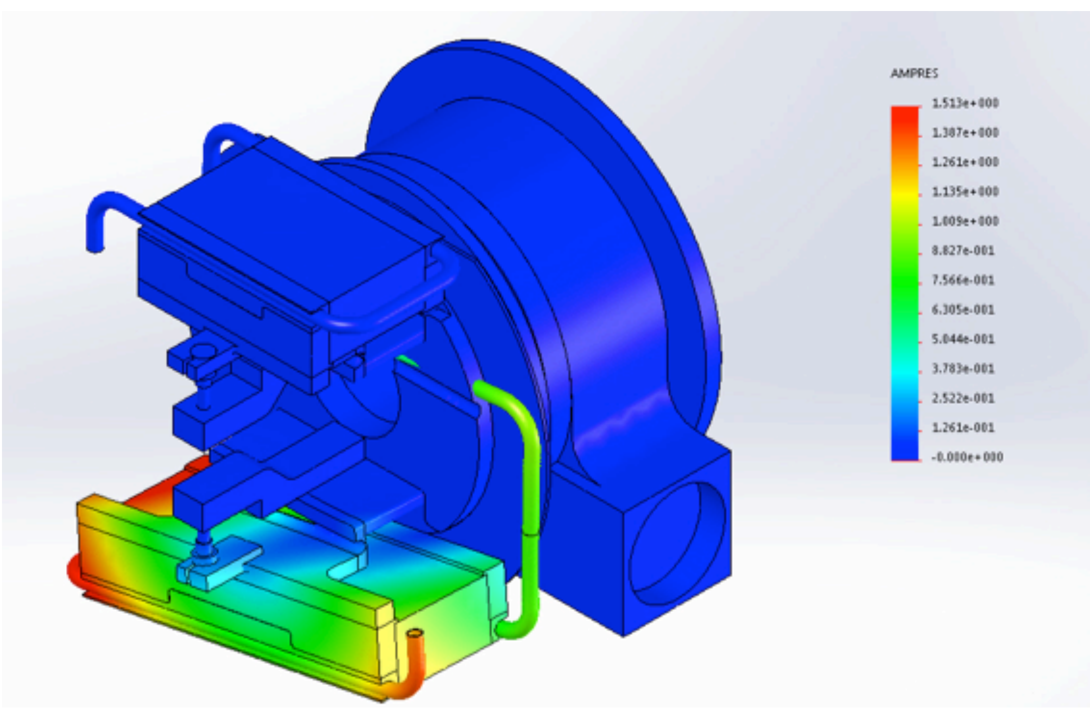
Mode 5 - 75Hz

Damaged Flexures

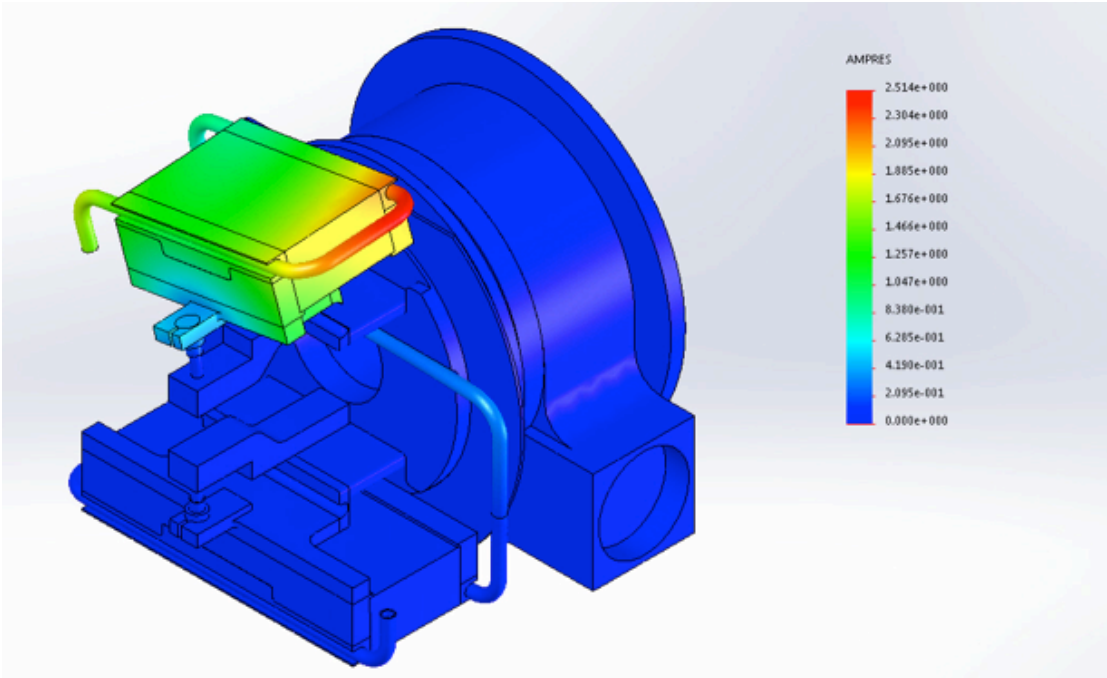
At some point during user operations the monochromator turrets collided damaging the flexure on the multilayer. Due to time constraints, the assembly was patched, but a replacement flexure was never installed. To simulate the damaged flexure, a section of it was cut away. The first and second modes are within the region of vibration from the water lines

The different harmonic resonances were determined to be:

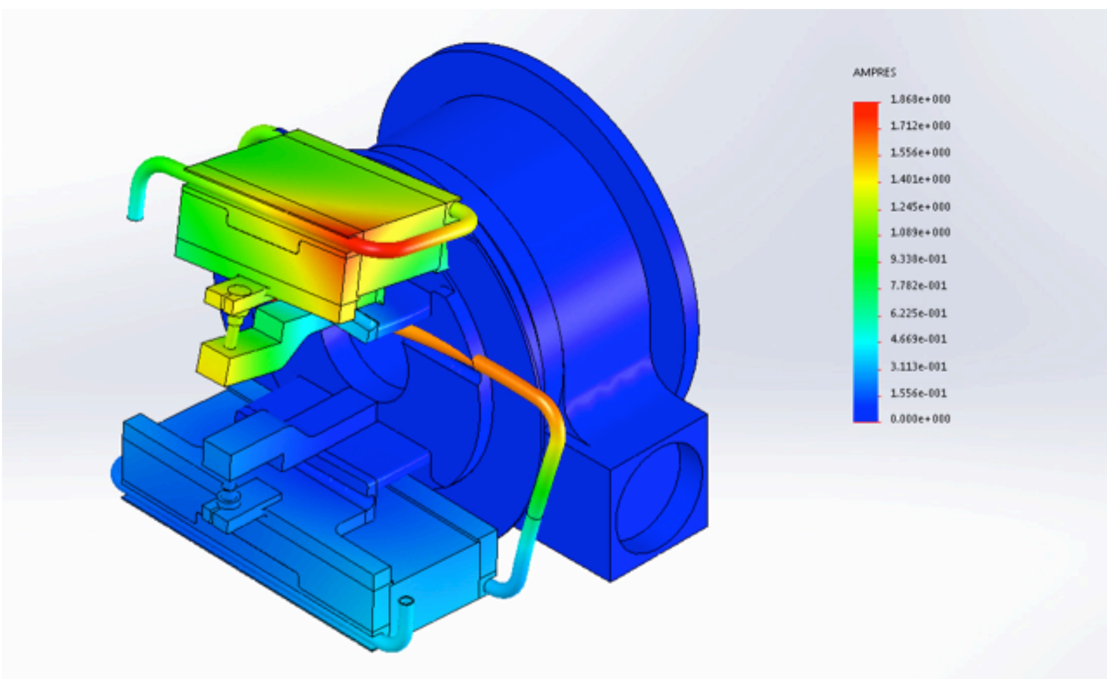
Mode	Frequency (Hz)	Section Affected
1	120 Hz	Multilayer and Cooling Lines
2	180 Hz	Si Xtal
3	215 Hz	Multilayer and Cooling Lines
4	230 Hz	Cooling Lines
5	275 Hz	Cooling Lines
6	287 Hz	Si Xtal and Cooling Lines
7	292 Hz	Multilayer and Cooling Lines
8	350 Hz	Cooling Lines
9	360 Hz	Multilayer
10	430 Hz	Si Xtal



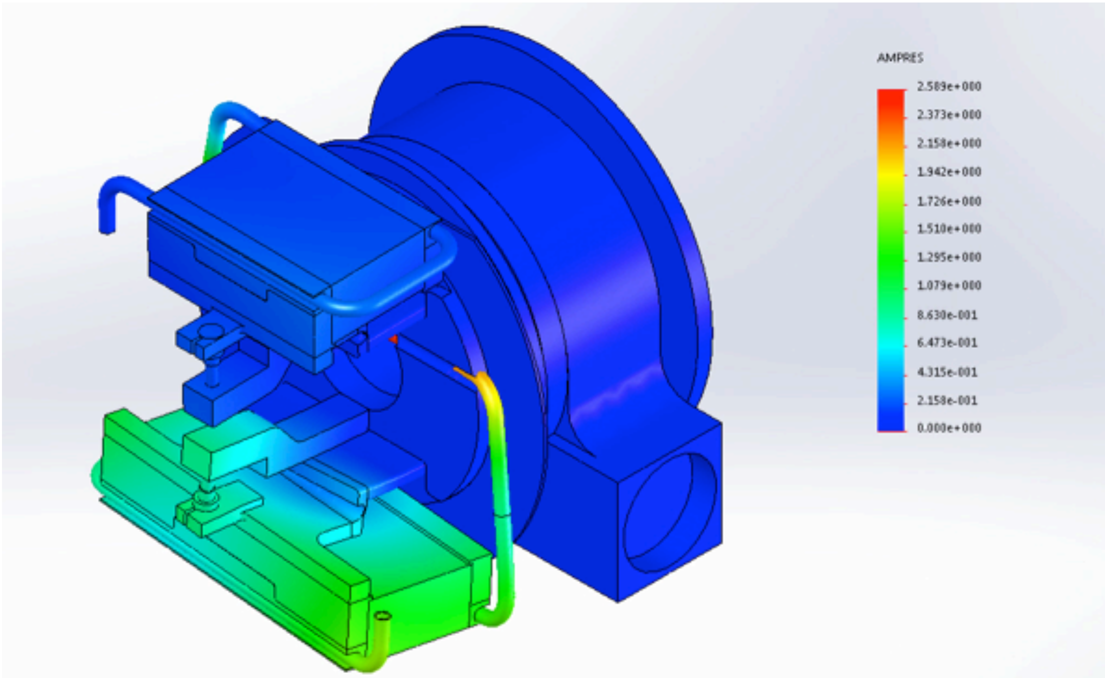
Mode 1 - 120Hz



Mode 2 - 180Hz



Mode 6 - 287Hz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1.942e+000
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1.510e+000
1.295e+000
1.079e+000
8.630e-001
6.473e-001
4.315e-001
2.158e-001
0.000e+000

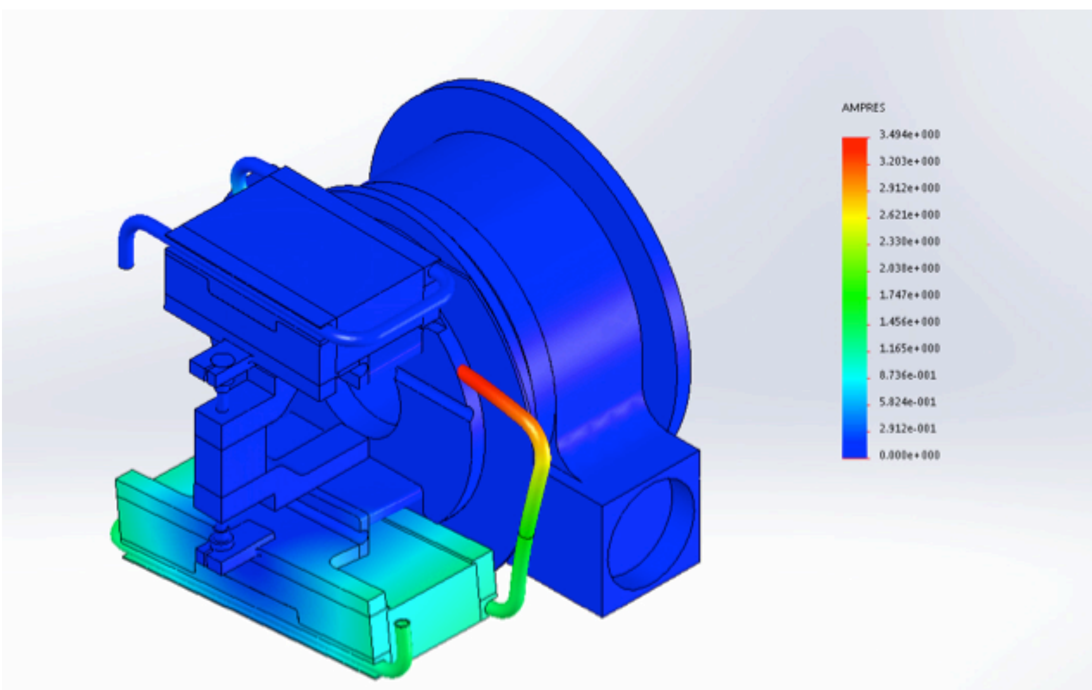
Mode 7 - 292Hz

Coupled Adjuster Mounts

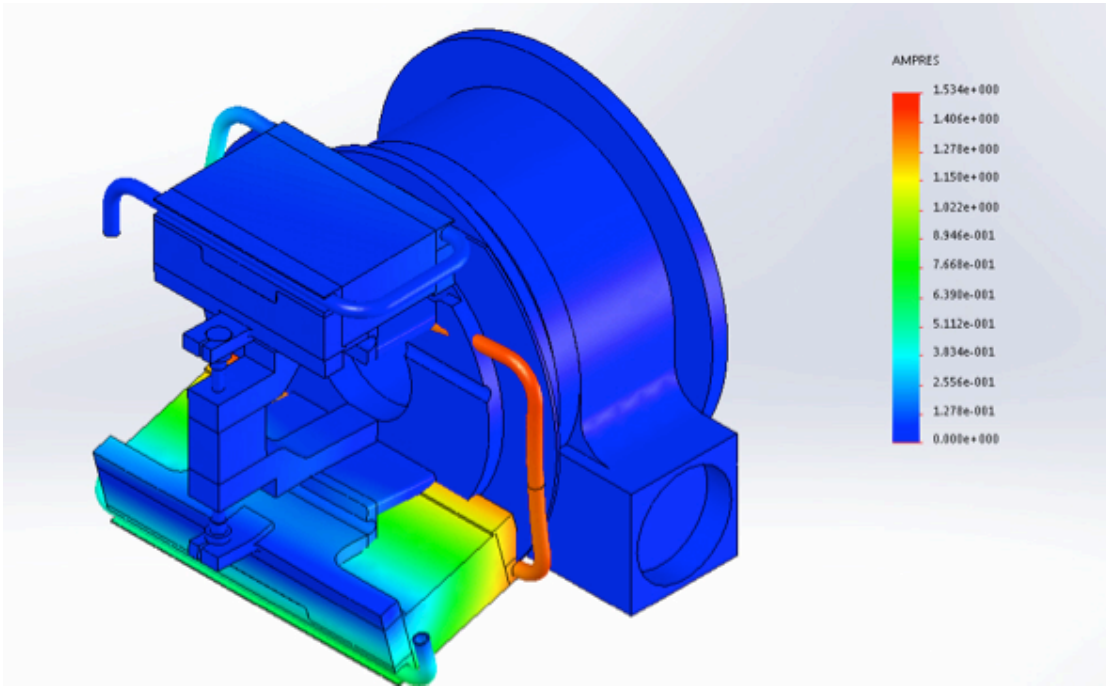
Each optical assembly is currently independently mounted, and each resulting cantilever is free to flex. This simulation looks at how much stiffer the assembly would get by adding in a coupling spacer between the two and joining them together.

The different harmonic resonances were determined to be:

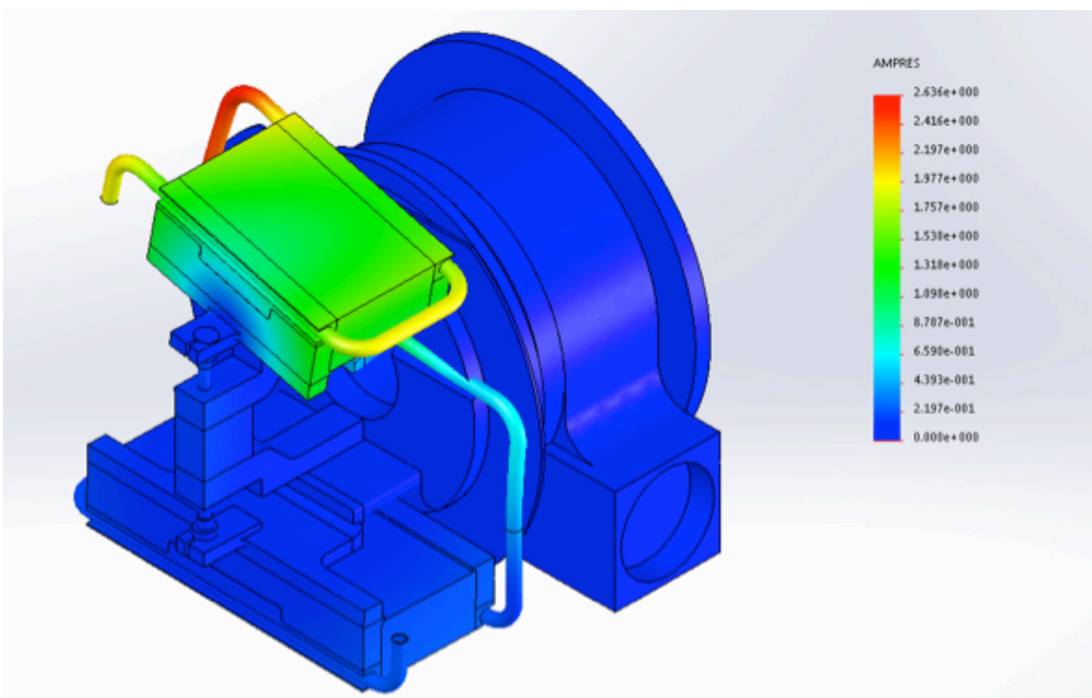
Mode	Frequency (Hz)	Section Affected
1	225 Hz	Cooling Lines
2	275 Hz	Multilayer and Cooling LInes
3	285 Hz	Cooling Lines
4	350 Hz	Cooling Lines
5	410 Hz	Multilayer and Cooling LInes
6	460 Hz	Si Xtal and Cooling Lines
7	520 Hz	Si Xtal and Cooling Lines
8	531 Hz	Multilayer and Si Xtal
9	670 Hz	Cooling Lines
10	790 Hz	Multilayer and Si Xtal



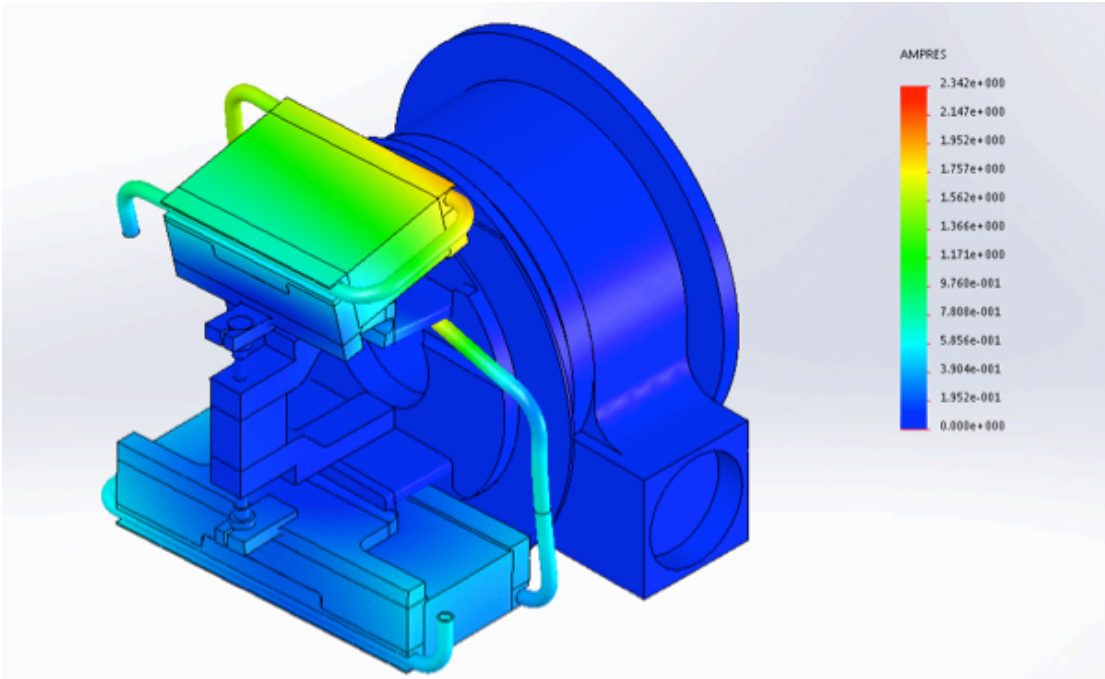
Mode 2 - 275Hz



Mode 5 - 410Hz



Mode 6 - 460Hz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7.808e-001
5.856e-001
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1.952e-001
0.000e+000

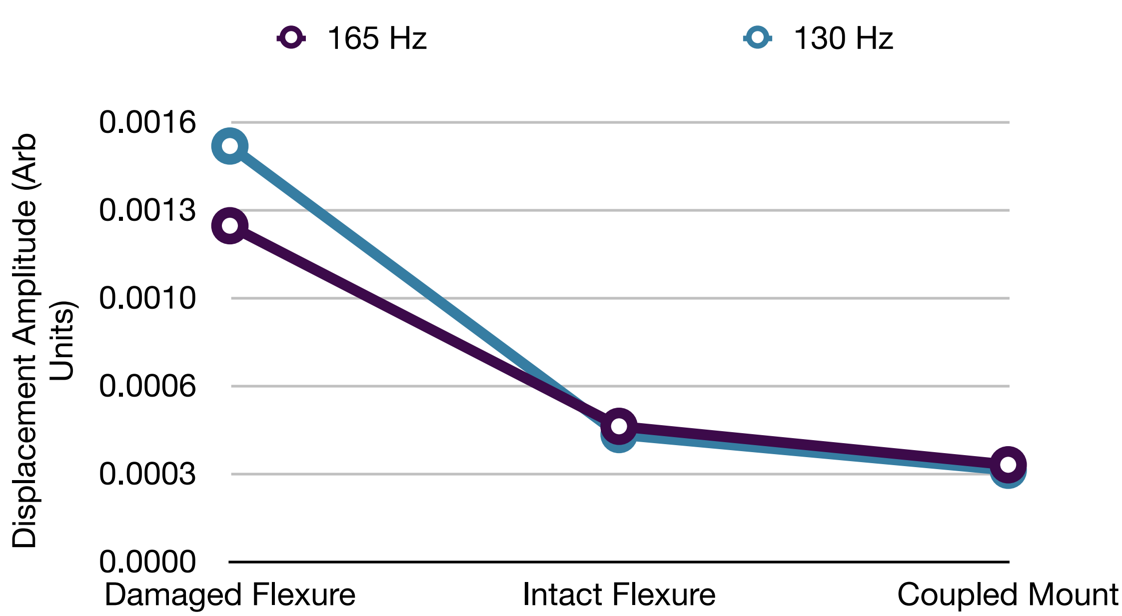
Mode 7 - 520Hz

Harmonic Response

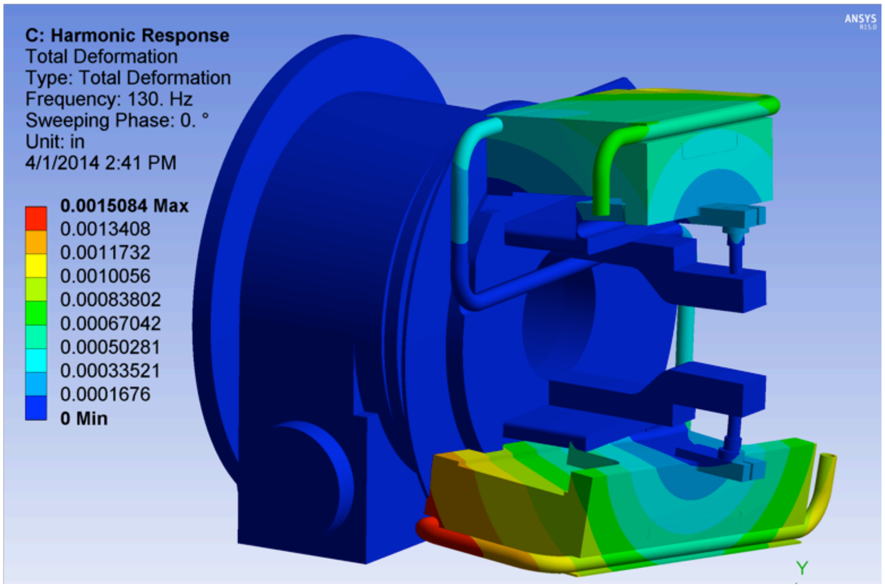
Full flow through the monochromator is approximately 1.5gpm and the line pressure is 50psi. A set of Harmonic Response analysis were done using ANSYS for the fixed and damaged flexures as well as the coupled mounting using this loading. Results are shown at 130Hz and 165Hz pulsing.

The maximum amplitudes of the assembly deflection at these frequencies are shown below:

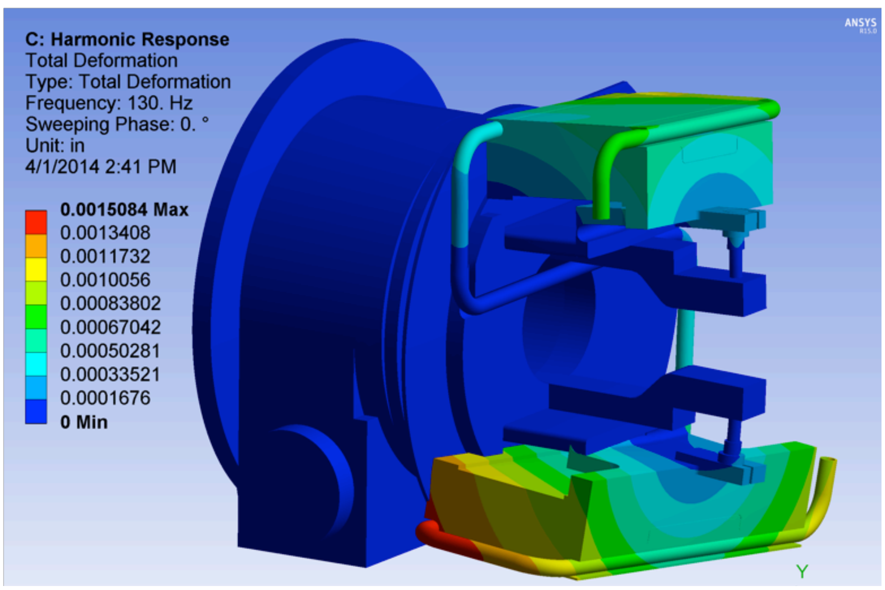
	130 Hz	165 Hz
Damaged Flexures	0.00151	0.00122
Undamaged Flexures	0.00046	0.00049
Coupled Adjuster Mounting	0.00033	0.00035



Damaged Flexure

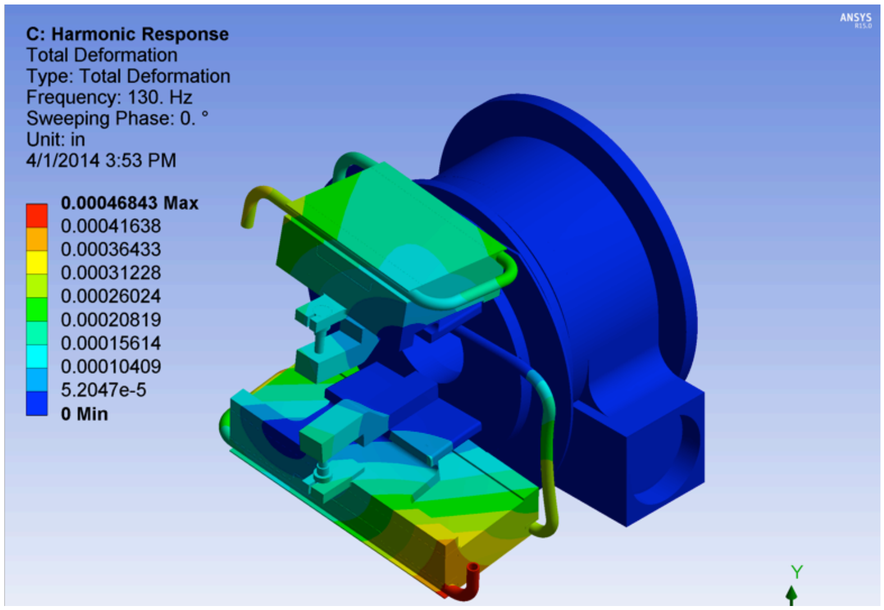


Damaged Flexure, 130Hz Water Hammer

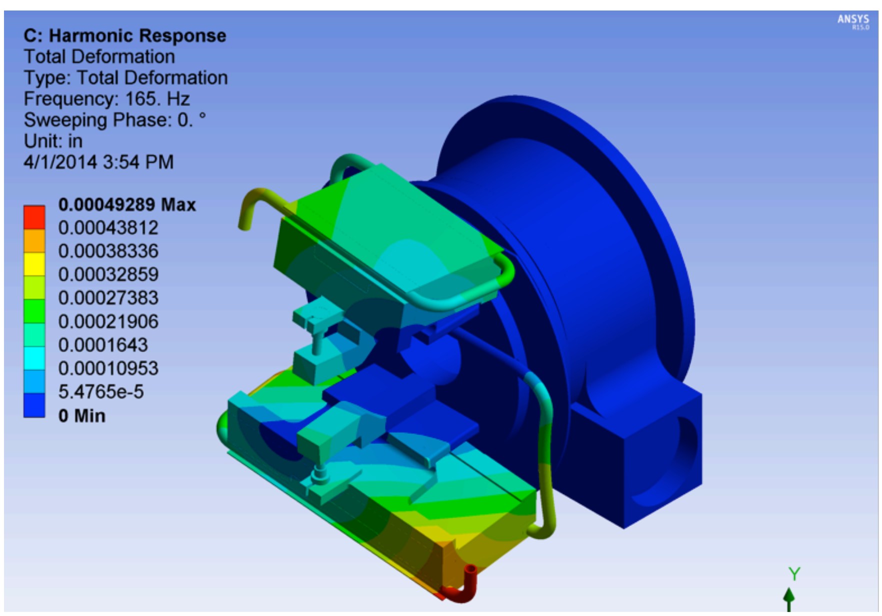


Damaged Flexure, 165Hz Water Hammer

Intact Flexure

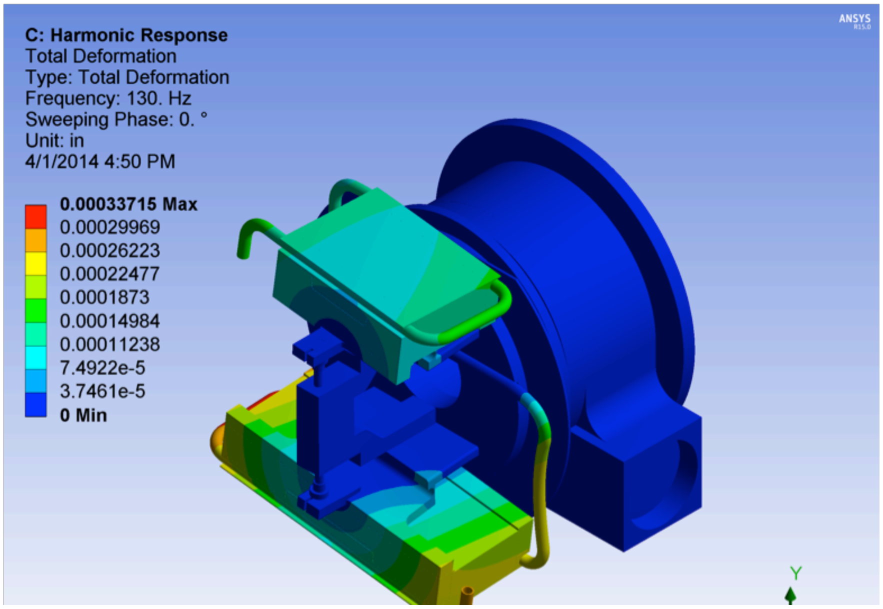


Intact Flexure, 130Hz Water Hammer

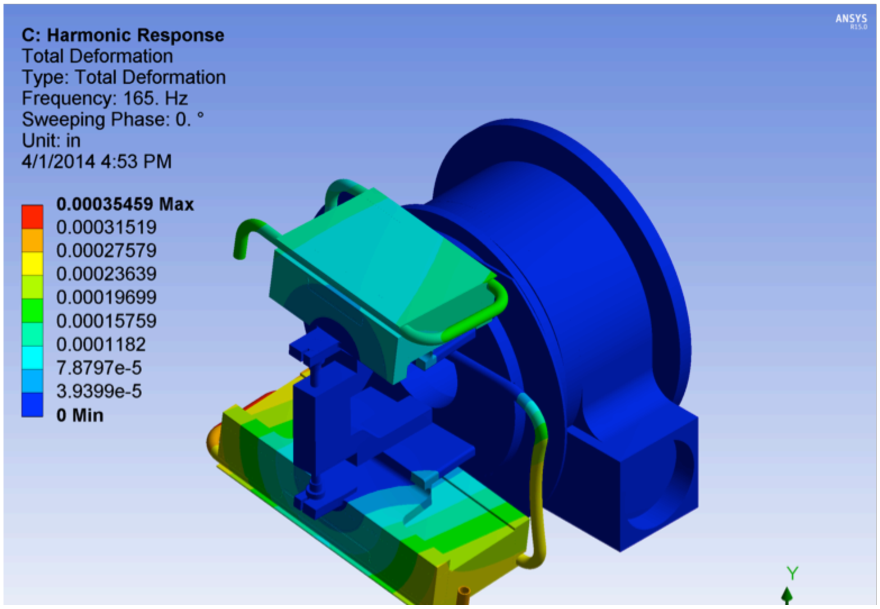


Intact Flexure, 165Hz Water Hammer

Coupled Adjuster Mounts



Coupled Mounting, 130Hz Water Hammer



Coupled Mounting, 165Hz Water Hammer

Recommendations

Replacing the damaged flexures on the optical assembly will stiffen the system and increase the harmonic modes to above 200 Hz. It will also reduce the influence of the water hammer induced vibrations by 60-65%

Coupling the adjuster screw mounting blocks will additionally remove around another 10% of the vibrations. It will also increase the The first mode will increase to 275 Hz, and the higher orders will be above 400 Hz.

It is recommended that both fixes be implemented