Experimental Modal Analysis Vibration Measurement to Inform Engineering Design

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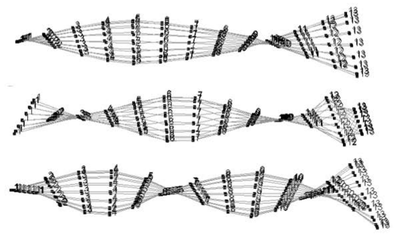
Summary

- *Experimental Modal Analysis was performed on an existing 5 degree of freedom mirror system on beamline I08 at the Diamond Light Source*
- *The new J08 system was engineered by IDT [1] incorporating the information from the modal analysis*
- *The new mechanism was designed, installed and tested*
- *The fundamental resonant frequency was significantly increased from 20 Hz to 49 Hz combined with a significant increase in damping.*

Introduction

Experimental Modal Analysis is a technique which allows a mechanical system's vibration mode shapes to be identified, quantified and visualised. This information can then be used to inform future design & operation. It is commonly used for everything from aircraft to tennis rackets.

Figure 1: Steel Beam Tests



I08-M4 Mirror System

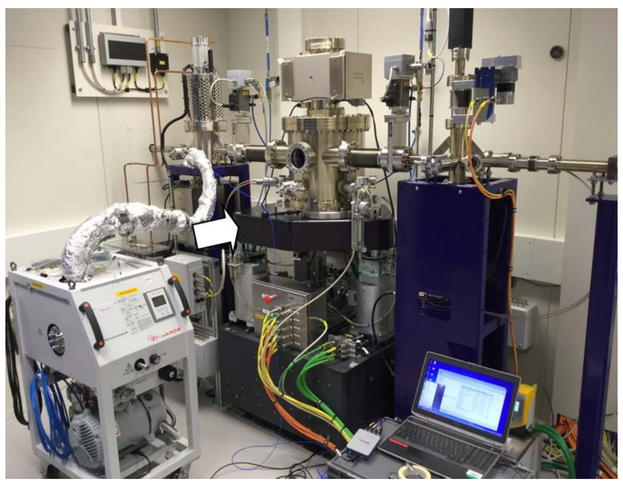


Figure 2: Mirror System I08-M4 at the Diamond Light Source. Modal Analysis Impact location & Direction indicated by arrow

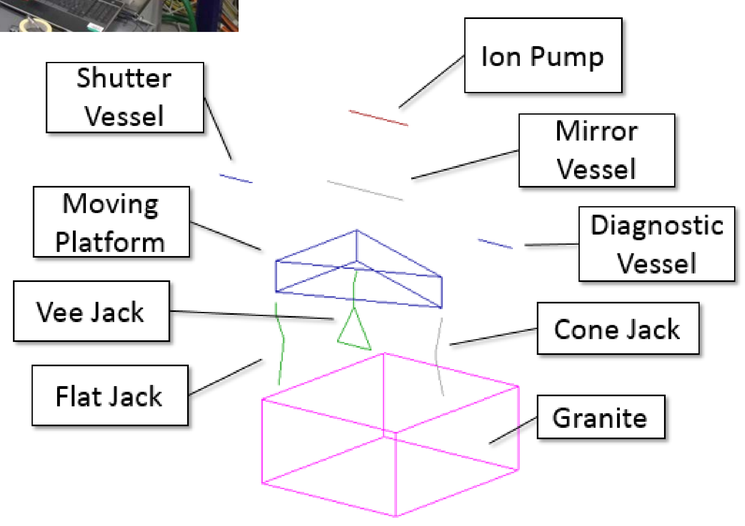


Figure 3: Modal Analysis Model of the mirror system within the M+P software [2]

Resonant Modes Identified from 14 Hz to 111 Hz

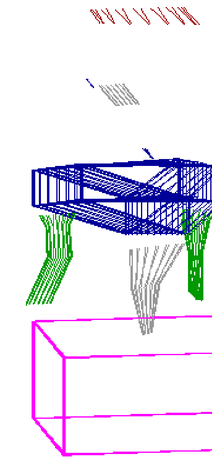


Figure 4: Mirror System I08-M4 Fundamental Translation Mode at 20 Hz

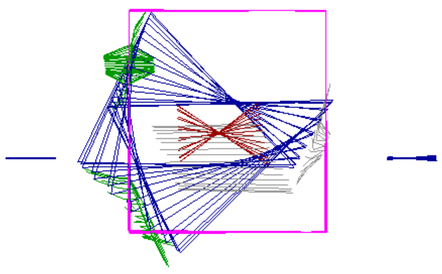


Figure 5: Example Ion Pump Resonant Mode 59 Hz, Plan View

New J08 Mirror System

Design Recommendations For IDT From Modal Analysis Results

- Move the ion pump to the diagnostic assembly to reduce the moving mass & remove a resonator
- Integrate pneumatic slide locks to fix the kinematic system during data capture
- Redesign the system to use rails with a higher moment stiffness to increase rocking resonance frequencies
- Reduce the mass of the motion platform
- Recess the spherical bearings into the moving plat-form to reduce leg length
- Reduce the jack travel & hence length to optimise for this application
- Mount the granite firmly to the concrete floor

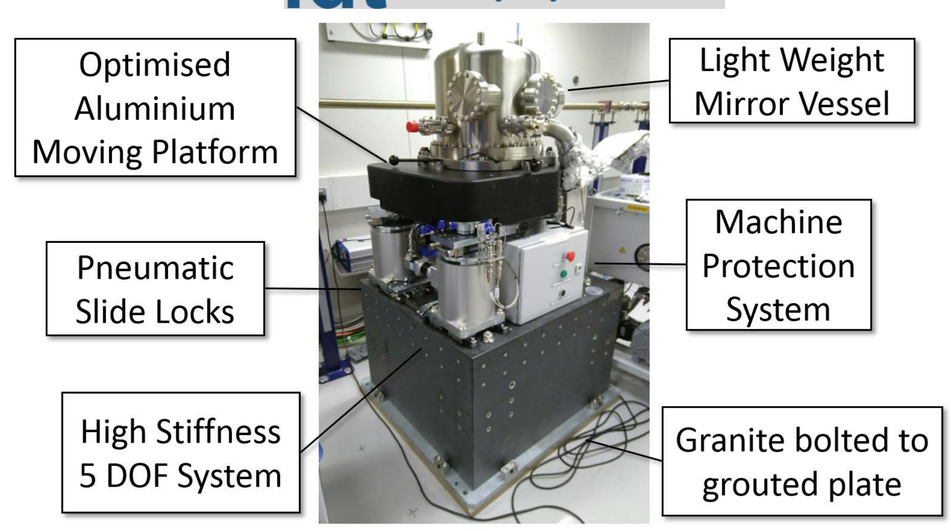
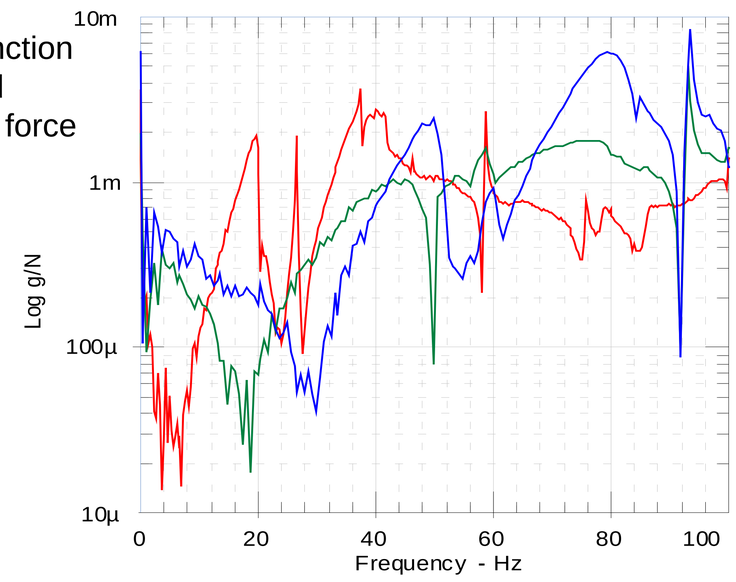


Figure 6: J08-M2 Mirror System Installed on the Beamline

A Frequency Response Function is a graph of measured acceleration per unit impact force vs. frequency

Figure 7: Comparison of Frequency Response Functions: Red I08-M4, Green J08-M2 Clamps Off, Blue J08-M2 Clamps On



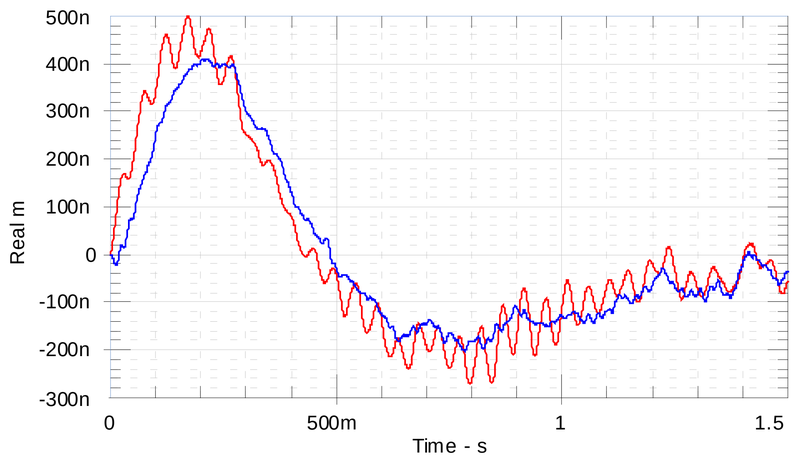


Figure 7: Comparison of Mirror System stability: Red = I08-M4, Blue = J08-M2

The original system position oscillated with an amplitude of ~ 100 nm whereas the new system stability is at the background vibration level of ~ 20 nm. Both traces nicely illustrate how the largest amplitude motion of the floor is at the lowest frequency with the beamline optics moving together

References

[1] Instrument Design Technology Ltd., http:///www.idtnet.co.uk
[2] M+P Intl., https://www.mpihome.com/en/