The Joy of Vibration Mitigation

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The Challenge

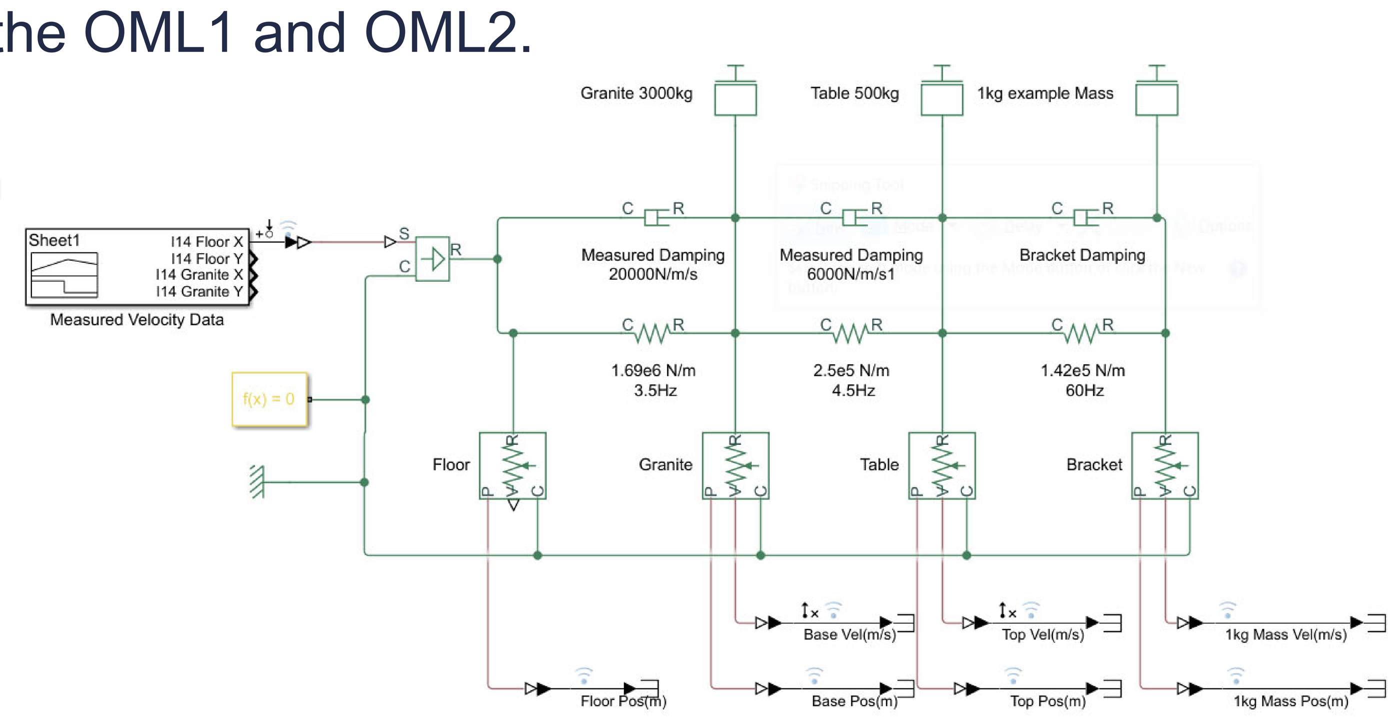
As part of the Diamond-II facility upgrade, a new Optics Metrology Lab has been built at Diamond Light Source. This replaced the old lab which will be demolished to make space for a “flagship” beamline. However, the location for the new lab has intermittent 100 times higher floor velocity in the range 50-150Hz. **The following presents two projects to mitigate the impact of this relocation**

Passive vibration isolation for an optical table

The new design reused existing optical breadboards supported via an intermediate granite block with 2 isolation stages i.e., floor to granite and granite to table. This provided an attachment method which didn’t over constrain the table as well as providing a steeper isolation slope with frequency.

An initial 2 degree of freedom (DOF) lumped mass model was created. This was then expanded to a 6 DOF ANSYS Modal Analysis to both visualise the mode shapes and to generate a reduced order model (ROM) for input into Simulink®.

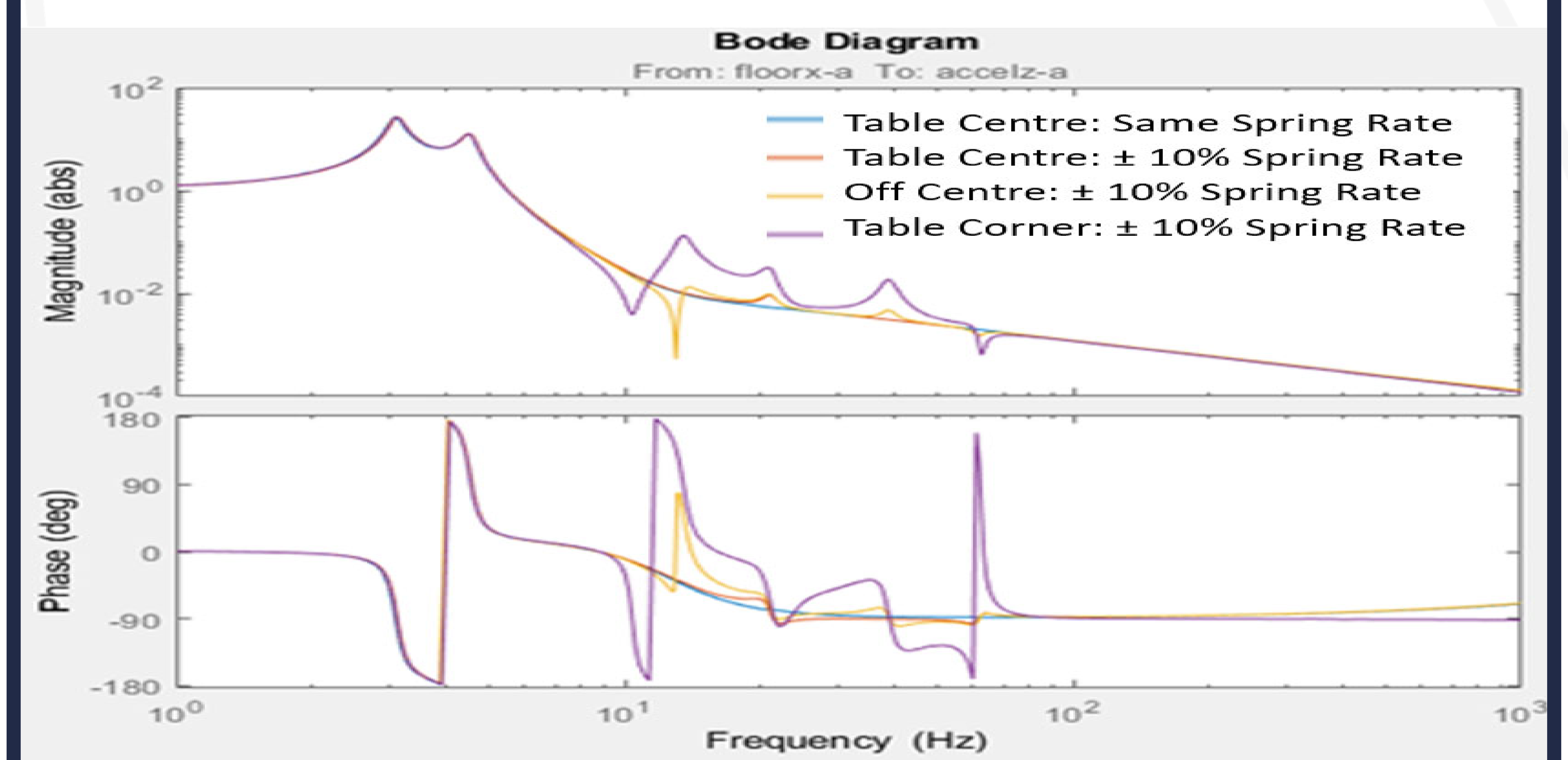
Accelerometer measurements were taken between 1 Hz and 500 Hz to compare the performance of the old and new tables in both the OML1 and OML2.

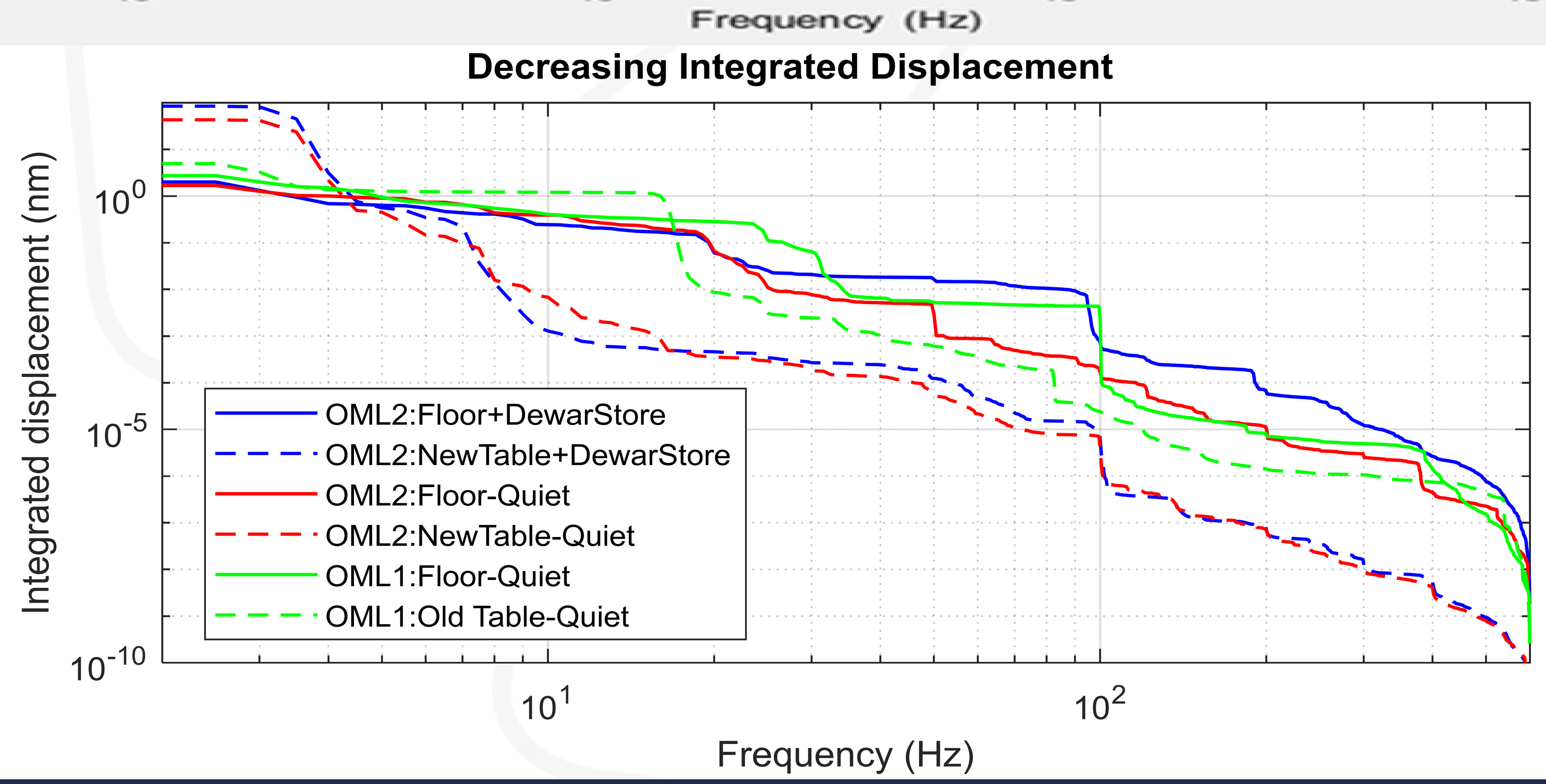


Simulink lump mass model of 2 DOF system.

***Fig A.** Floor to tabletop 6 DOF simulations to show the effect of varying the spring stiffness and sensor location.*

***Fig B**. Measured accelerometer data plotted as an integrated displacement running from high to low frequency.*

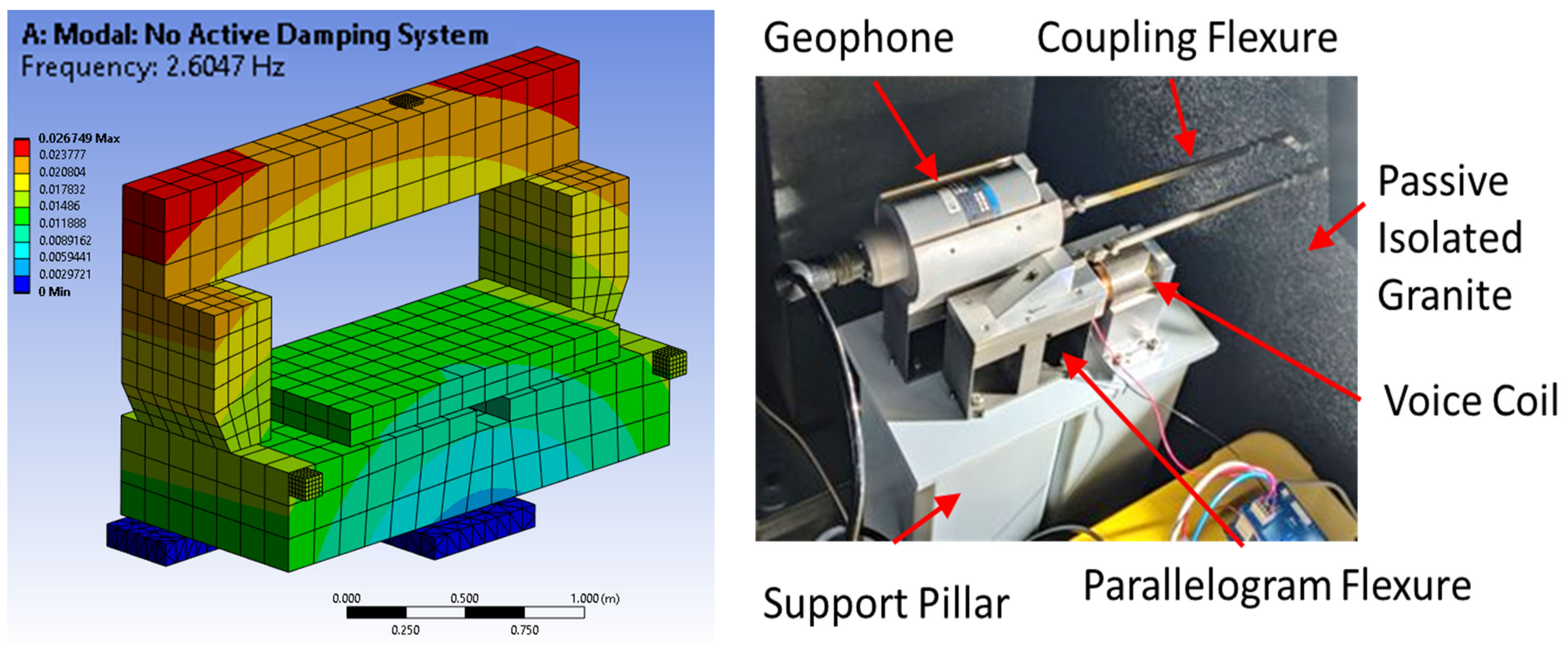




Actively damping a non-contact profilometer

The Diamond Nano Optical Metrology (NOM) instrument is a non-contact profiler capable of characterizing optical figure error with sub-nm repeatability. To maintain performance after relocation, the NOM was fitted with spring mount isolators. This successfully mitigated >6 Hz vibrations.

However, an undesirable effect was that the acceleration reaction forces from the scanning stage caused the granite system to resonate at ~2 Hz. This created secondary reaction forces back to the scanning stage corrupting the dynamic, optic slope error measurement.

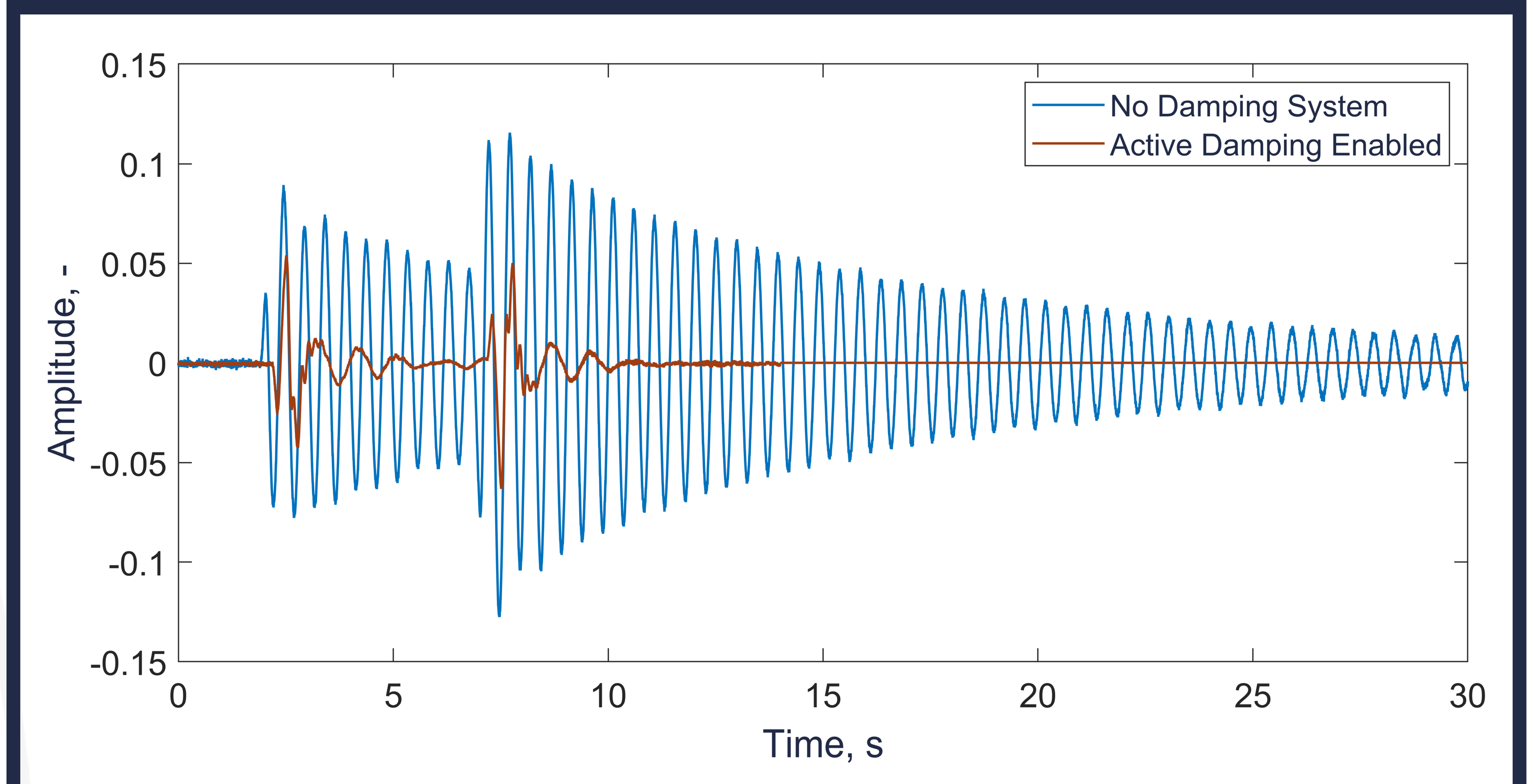


FEA model (left), photograph of implemented system (right).

To solve this, a ROM was exported from ANSYS® via APDL code. The ROM was used as the plant block in a Simulink model to capture the 6 DOF complexity of the lowest 20 mode shapes. A simple ‘skyhook’ damping i.e., **active damping using geophone velocity feedback** was simulated[1]. This informed the optimum placement and geometry of the active damping system.

The voice coil actuator and geophone were individually connected to the granite base via titanium flexure couplings to enable high stiffness, zero backlash actuation and sensing. The system operated in closed loop via an Omron CK3M controller.

Velocity vs. time measurement of NOM, comparing scanning stage jog motion with and without the active damping system.



Conclusions

Both projects successfully tackled challenges relating to vibrational stability:

- The passive system successfully isolated the floor vibrations, leaving background acoustics as the dominant disturbance.
- The active damping system applied to the NOM reduced settle time between steps by an order of magnitude. This enabled scanning to be performed far more quickly, increasing throughput, whilst also reducing measurement error.
- Both methodologies can be applied to similar systems which require exceptional vibrational stability.

References [1] R. Munnig Schmidt, G. Schitter, and A. Rankers, The Design of High-Performance Mechatronics - 3rd Revised Edition, 3rd ed. IOS Press, 2020.