Auxiliary Suspension Modelling for Glasgow Cryogenic Interferometer Facility

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Introduction to GCIF

The Glasgow Cryogenic Interferometer Facility (GCIF) will be a double cavity cryogenic interferometer prototype. This facility will allow the testing of future technologies required for 3rd generation detectors such as suspended silicon optics, materials research, and cryogenics research. The GCIF will have a 10 m room-temperature reference cavity, leading to a 0.1 m optical cavity with suspended silicon optics cooled to 123 K.

Once completed, there are many experiments which could be performed at this facility, such as the study of base noise performance of silicon suspensions, optimisation of control at 123 K, and study of ice formation on silicon optics.

Auxiliary Suspension Design

The suspensions design phase began with one of the room temperature steering optics to be used for beam steering, therefore it must have low enough noise that the contribution from multiple optics will not rise above the thermal noise floor of the cavity. This steering mirror will be placed in a small vacuum chamber, and therefore also must have a compact design.

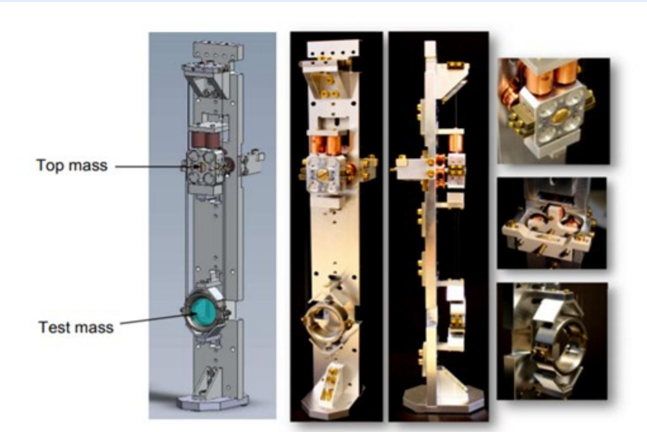

Figure 1: Auxiliary suspension CAD model, and completed suspension build [1]

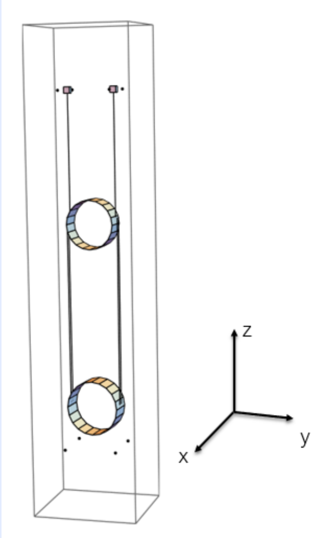

Figure 2: Auxiliary suspension Mathematica model.

We modified a version of an auxiliary suspension previously designed by J Hennig and R. Jones[1], shown in Figure 1. This design has a 5 x 8 cm footprint with a height of 30 cm, and previously exhibited a modelled displacement noise due to coupling of seismic ground motion below 8×10^{-15} $mHz^{-1/2}$ at 100 Hz.

A Mathematica model allowed the addition of passive isolation and changes to the support tower. An existing double pendulum model was used with the parameters changed to match those of the auxiliary suspension shown in Figure 2. The resonant frequencies of this model occurred at low enough frequencies to be out of the predicted sensitivity range, however there is a vertical bounce mode occurring at around 90 Hz which could add noise into the system. Damping this bounce mode was the aim with the next steps of this model.

Passive Isolation

Viton was chosen as passive isolation to dampen the suspension's vertical bounce modes, and was added at the tower base and wire mounting points. Plotting the vertical transfer functions of the model pre- and post- Viton show a 100x decrease in this mode and a decrease in the Q-factor from 5800 to 210.

The effect of the auxiliary suspension on the optical cavity length noise was then explored. The transfer function of the model was multiplied by a seismic spectrum, outputting the frequency-dependent effective cavity length noise created by vertical motion at the base of the suspension. This is done to ensure that the noise added to the system by this steering suspension is lower than the thermal noise floor in the optical cavity.

Results

Above 10 Hz the model containing the passive isolation shows a decrease in length noise in comparison to the basic double pendulum model, which becomes more prominent at higher frequencies – both the direct vertical noise and coupled horizontal have decreased by a factor of 1000 at 500 Hz, shown in Figure 3. This plot will help in modifying the auxiliary suspension design based on noise requirement levels.

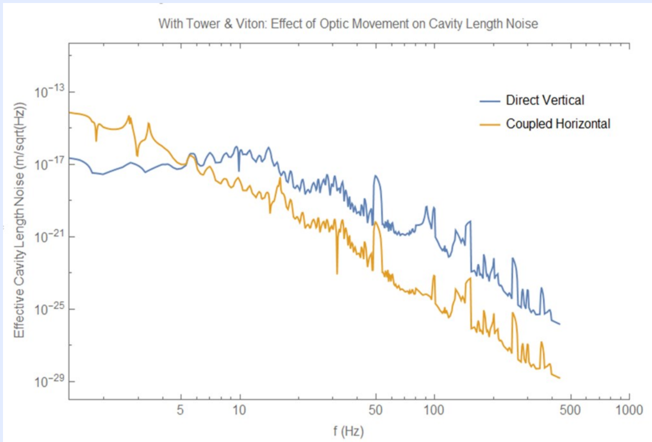

Figure 3: Effective length noise in optical cavity from motion at base of suspension from Mathematica model with double pendulum, support tower, and Viton.

Future Work

The design phase of the auxiliary suspension is ongoing. Future steps could be design modifications to stabilise the support tower against pitch and roll modes, and to carry out Viton property analysis though Finite Element Analysis (FEA) modelling or experimental work to calculate spring constant and Q-values based on Viton geometry.

1. J Hennig. "Mirror Suspensions for the Glasgow Sagnac Speed Meter". PhD thesis. University of Glasgow, 2018.