FEA modelling of Cryogenic suspension system

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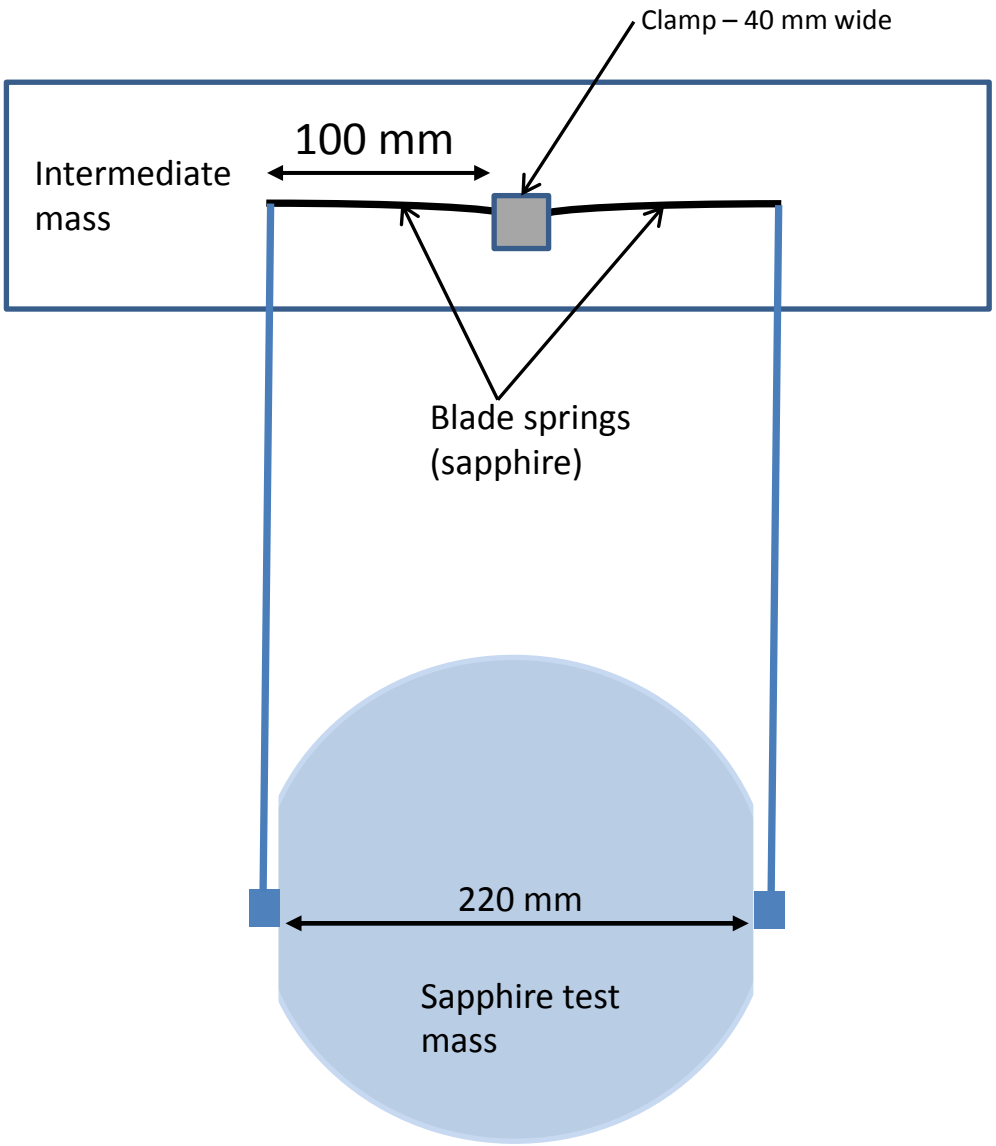
Outline

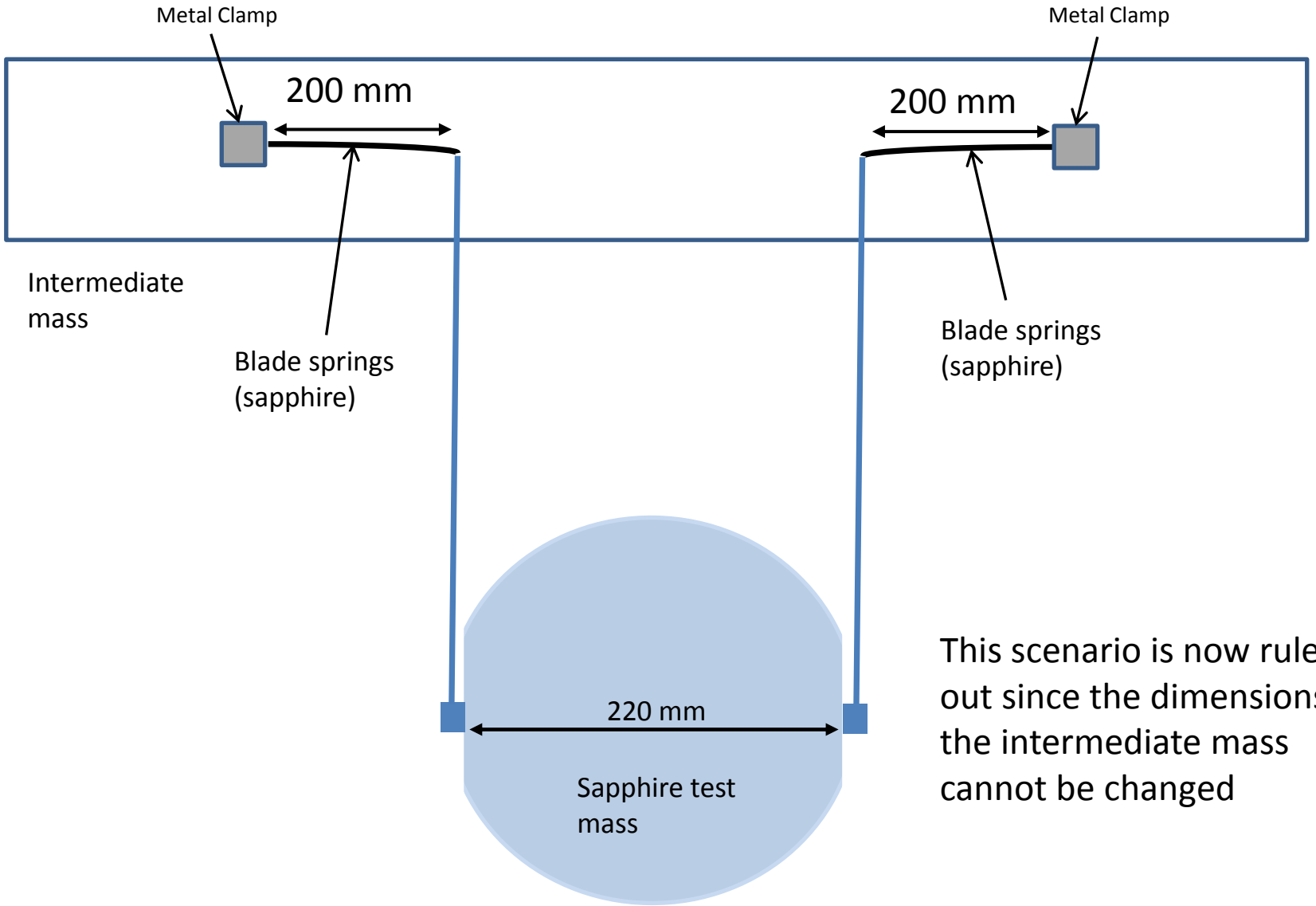
- Sapphire blade springs development
- Modelling of Indium layer
- Estimation of Violin mode
- Ongoing and future work

Sapphire blade springs development

Suspension layout - 1

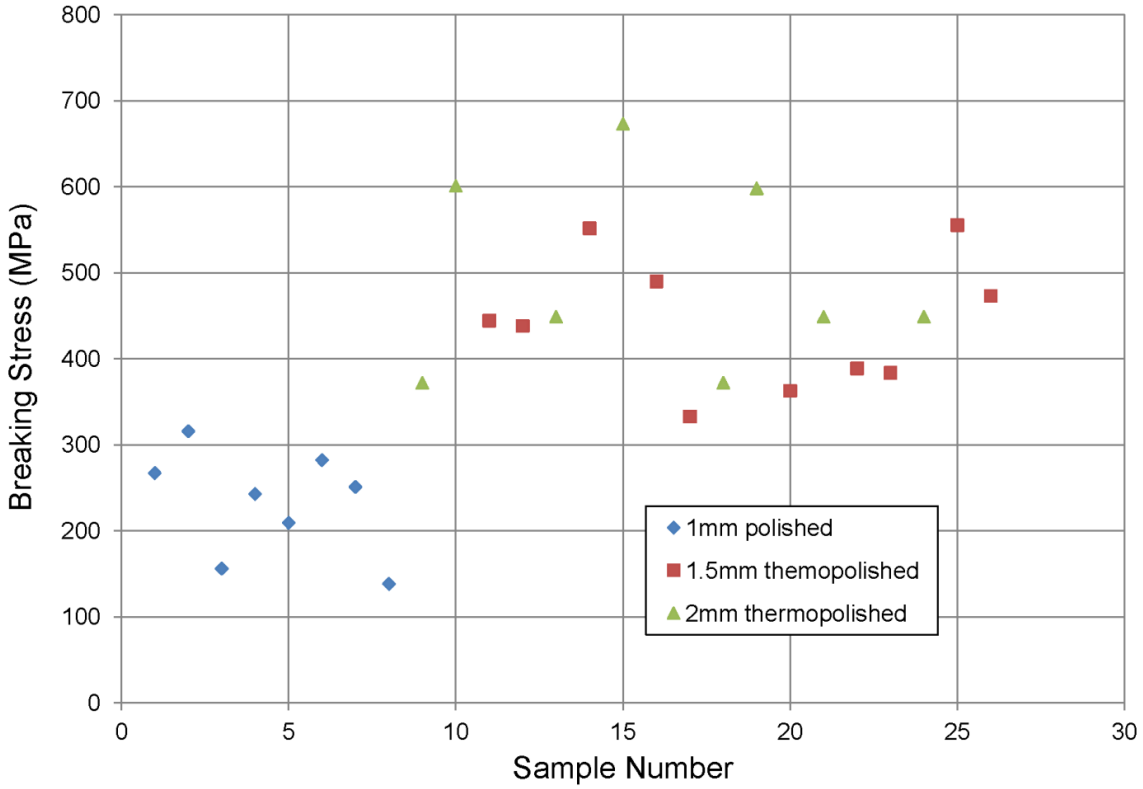


Suspension layout - 2



This scenario is now ruled out since the dimensions of the intermediate mass cannot be changed

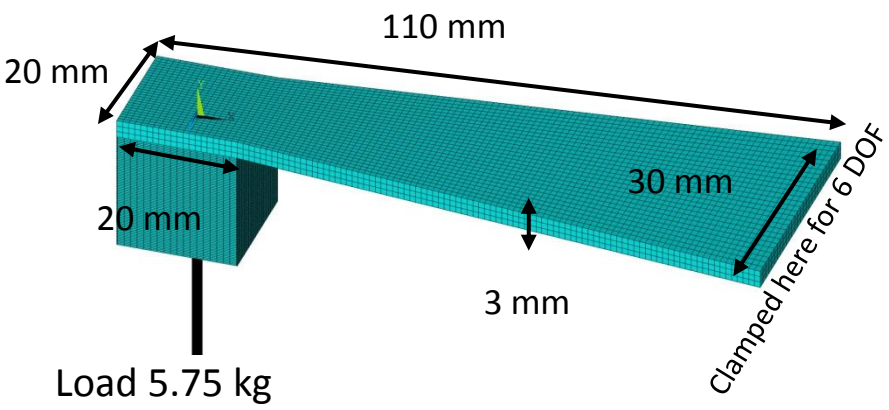
Breaking stress of sapphire blades



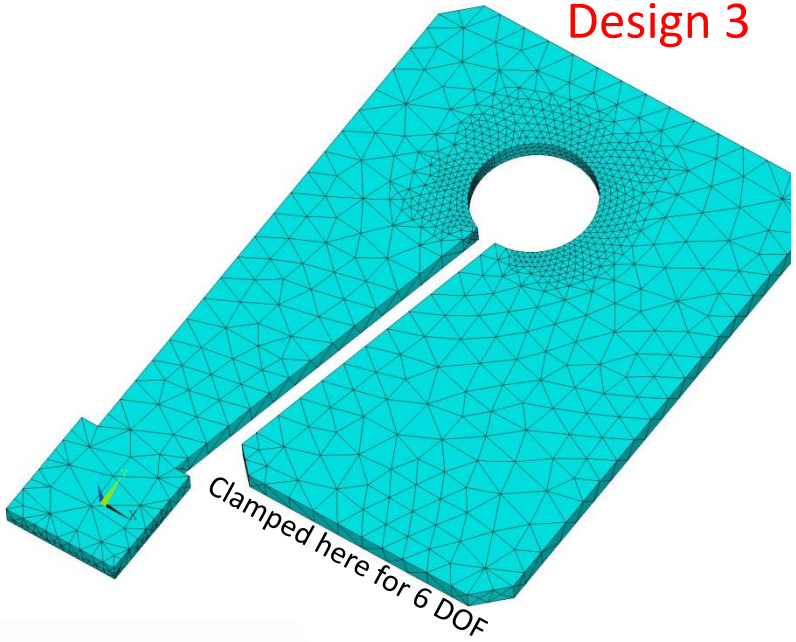
Experiment conducted in Glasgow

- Thermo-polish gives an average breaking stress of 466 MPa. Non polished blades have lower breaking stress of 250 MPa. For KAGRA thermo polished sapphire blade springs will be used.

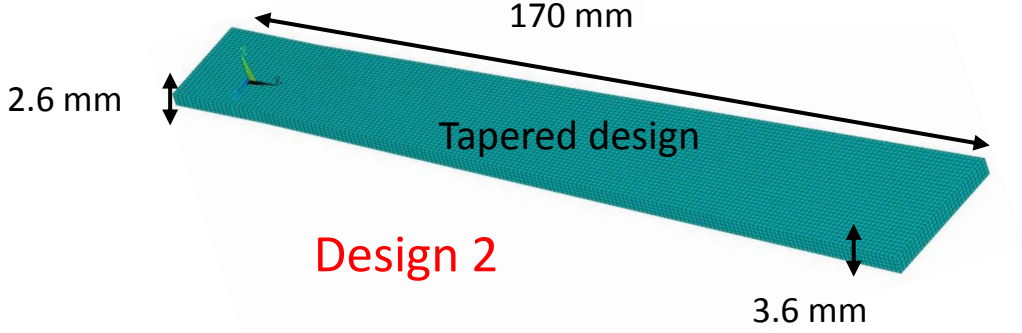
Prototype designs



Design 1



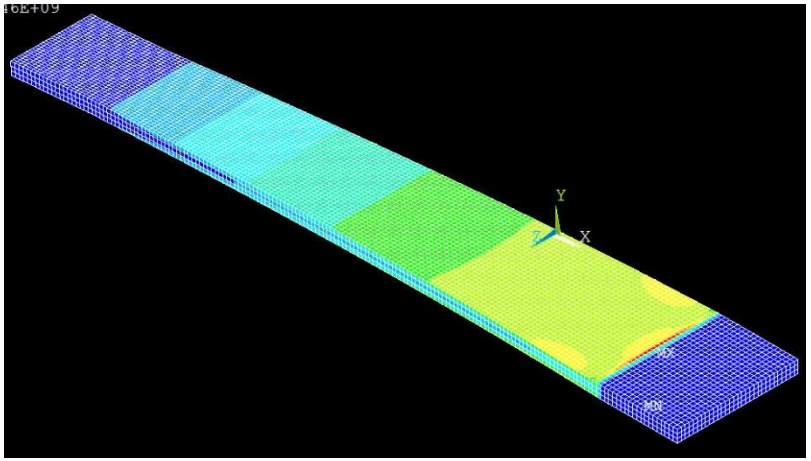
Design 3



Design 2

Blade Springs are required to lower the vertical (bounce) frequency which currently sits at 108 Hz.

Results

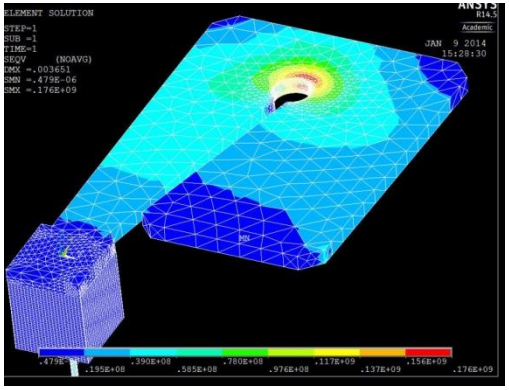


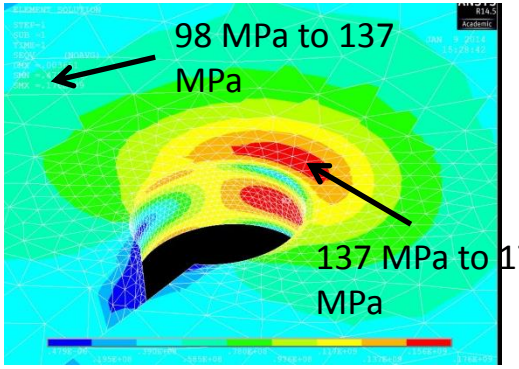
Design 1

Bounce mode frequency - 19.5 Hz

Design 2

Bounce mode frequency - 9.9 Hz





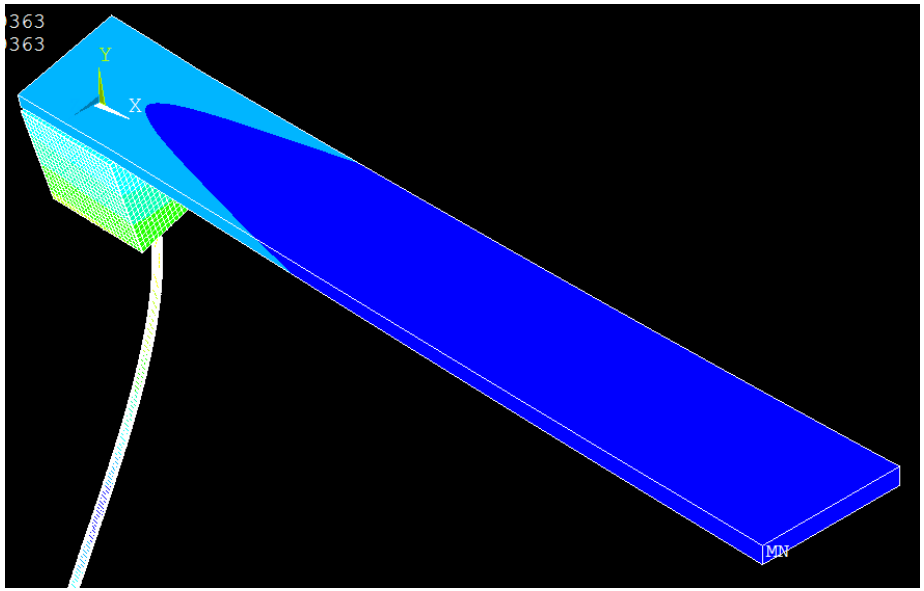
Design 3

Bounce mode frequency - 18.9 Hz

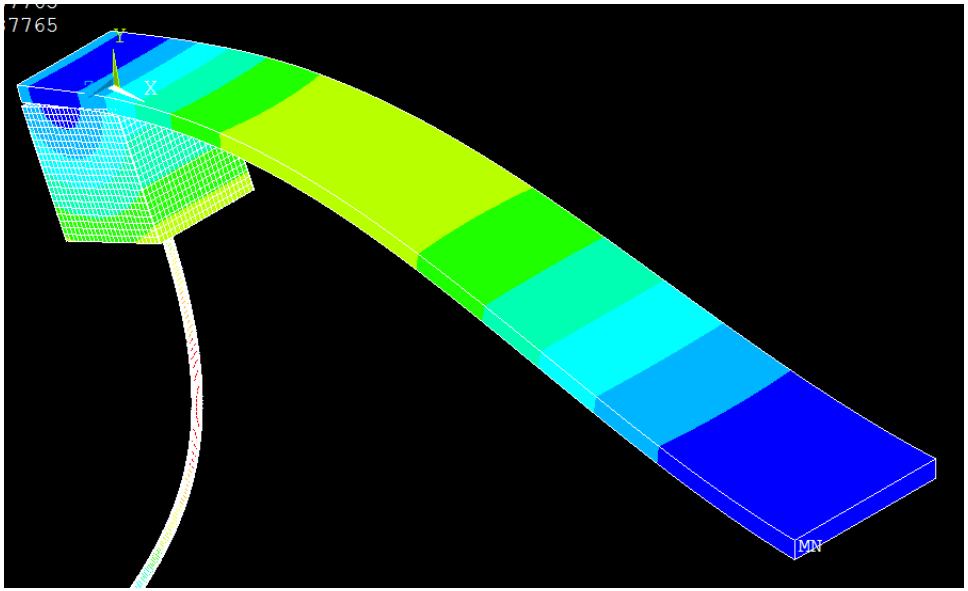
Work ongoing for design 3

Bending modes of the blades

The first and the second bending mode of the sapphire pendulum with blade springs is observed at 569 Hz and 767 Hz respectively.



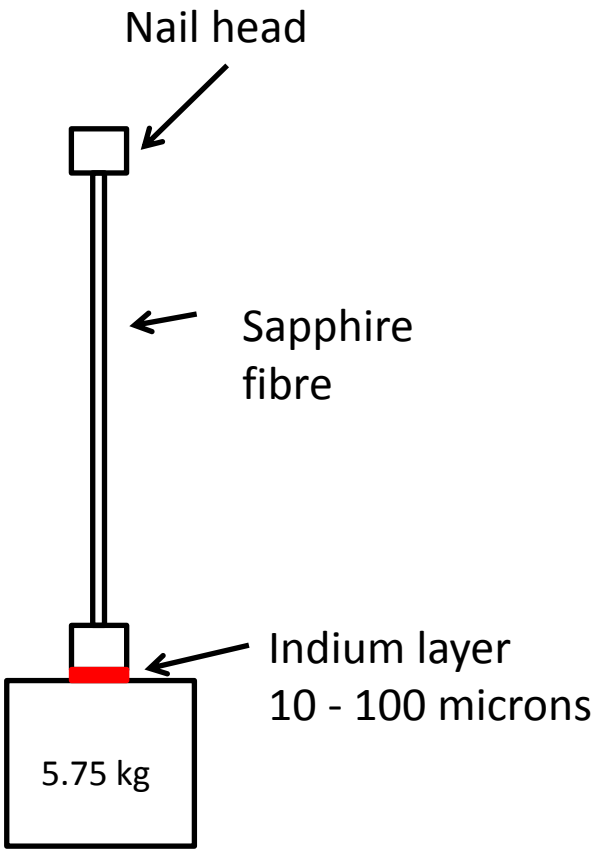
1st bending mode – 569 Hz

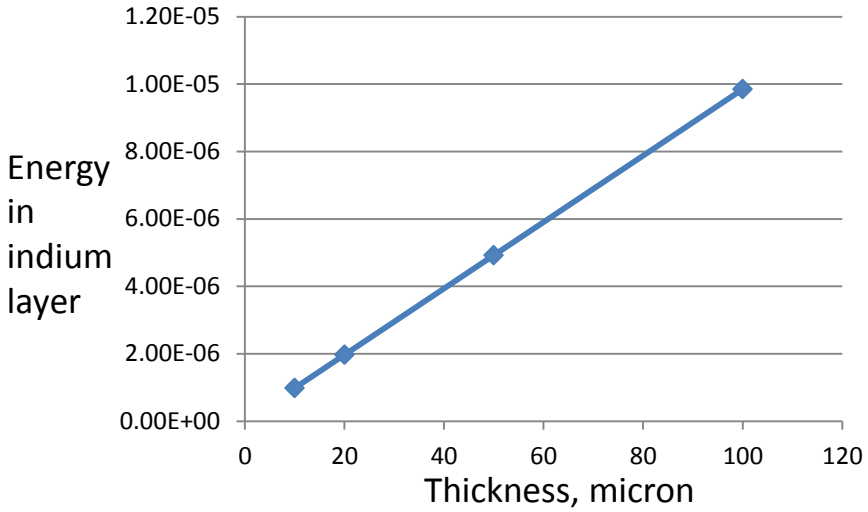


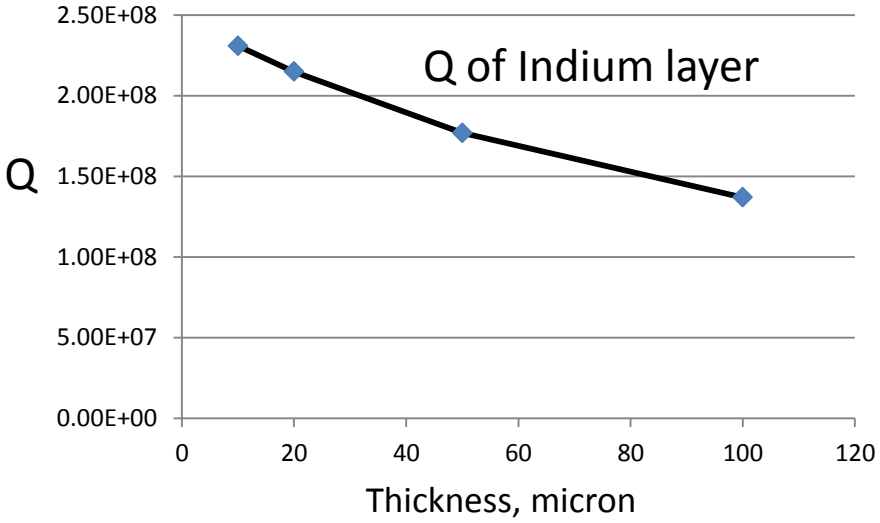
2nd bending mode – 767 Hz

Modelling of Indium layer

Estimating mechanical loss of Indium using FEA

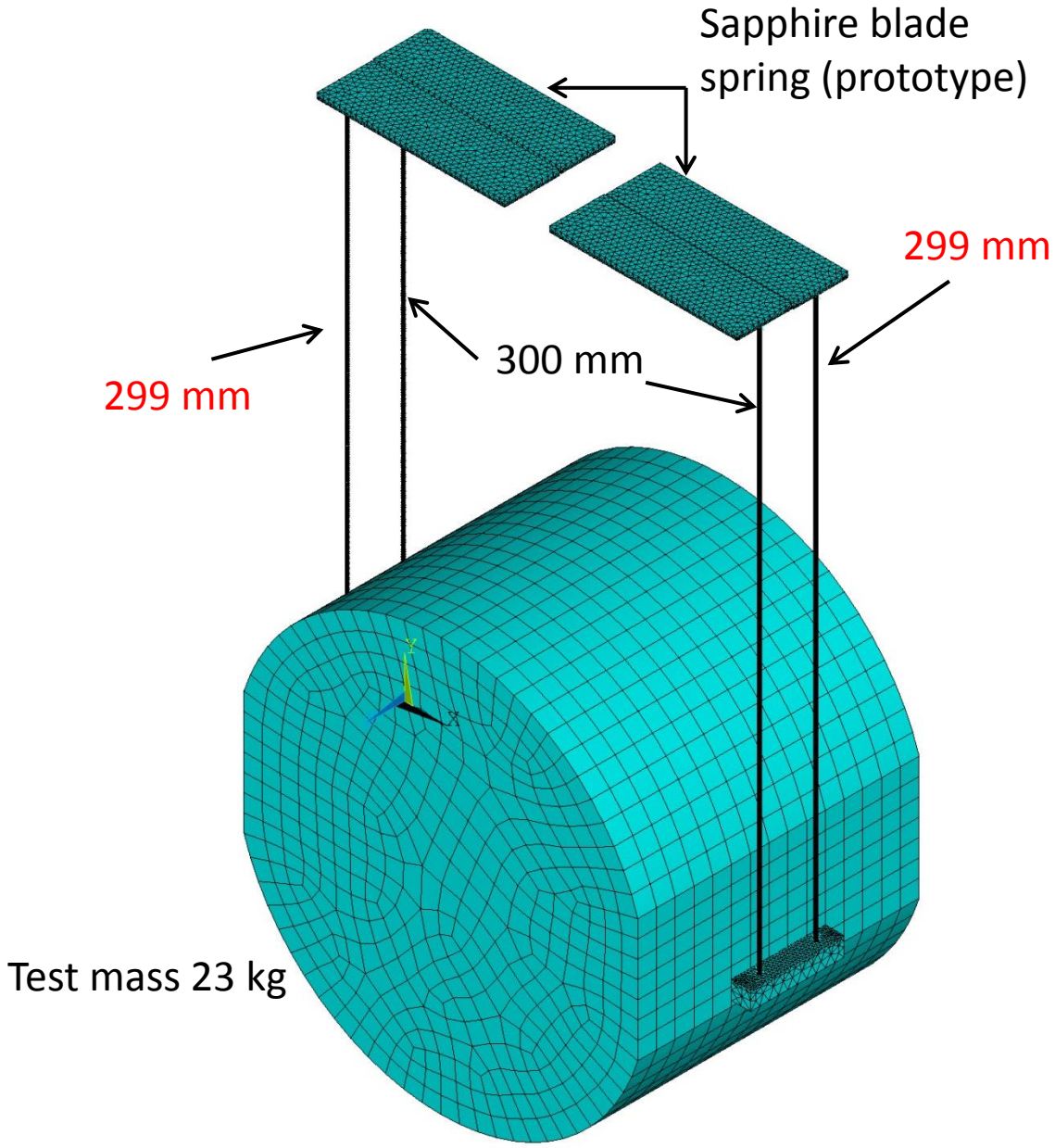


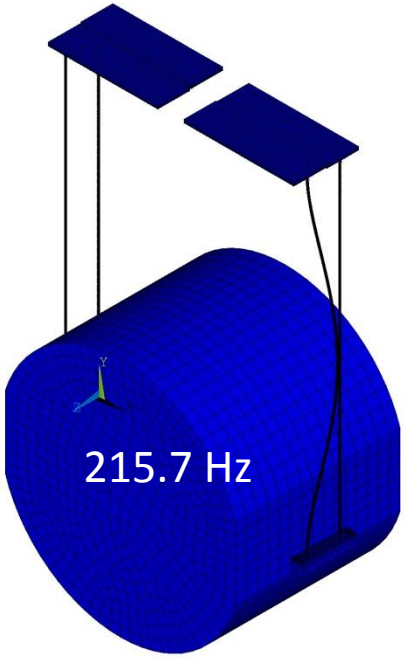


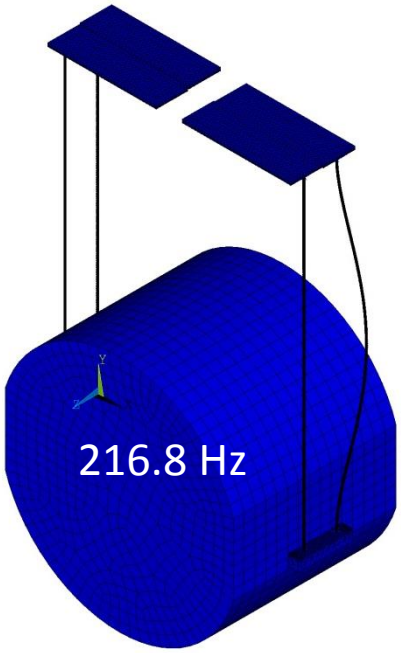


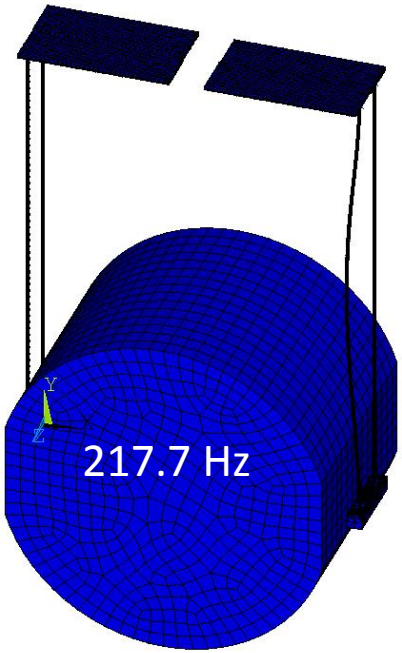
Q decreases by a factor of 1.7 when thickness is increased by a factor of 10

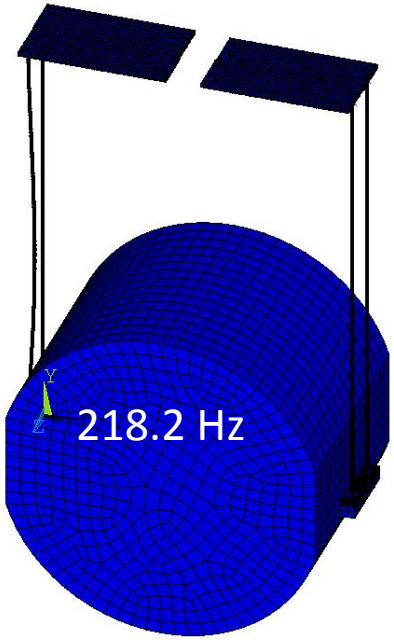
Estimation of Violin modes

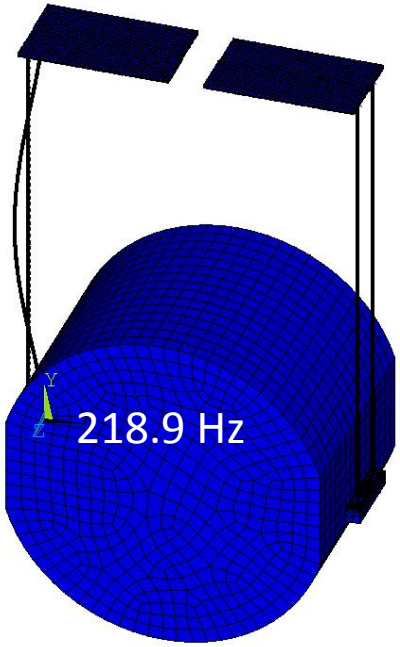

Sapphire blade
spring (prototype)
299 mm
300 mm
299 mm
Test mass 23 kg

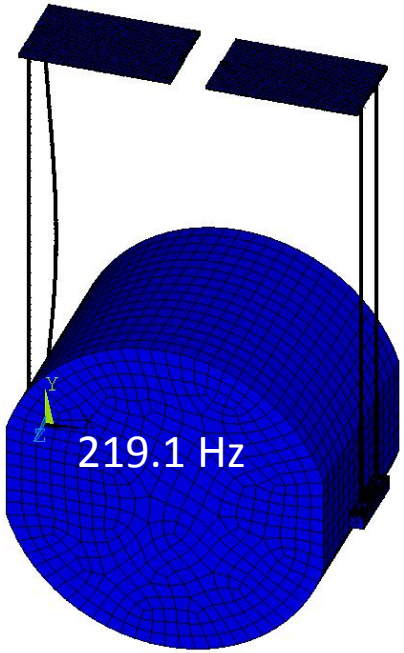

215.7 Hz

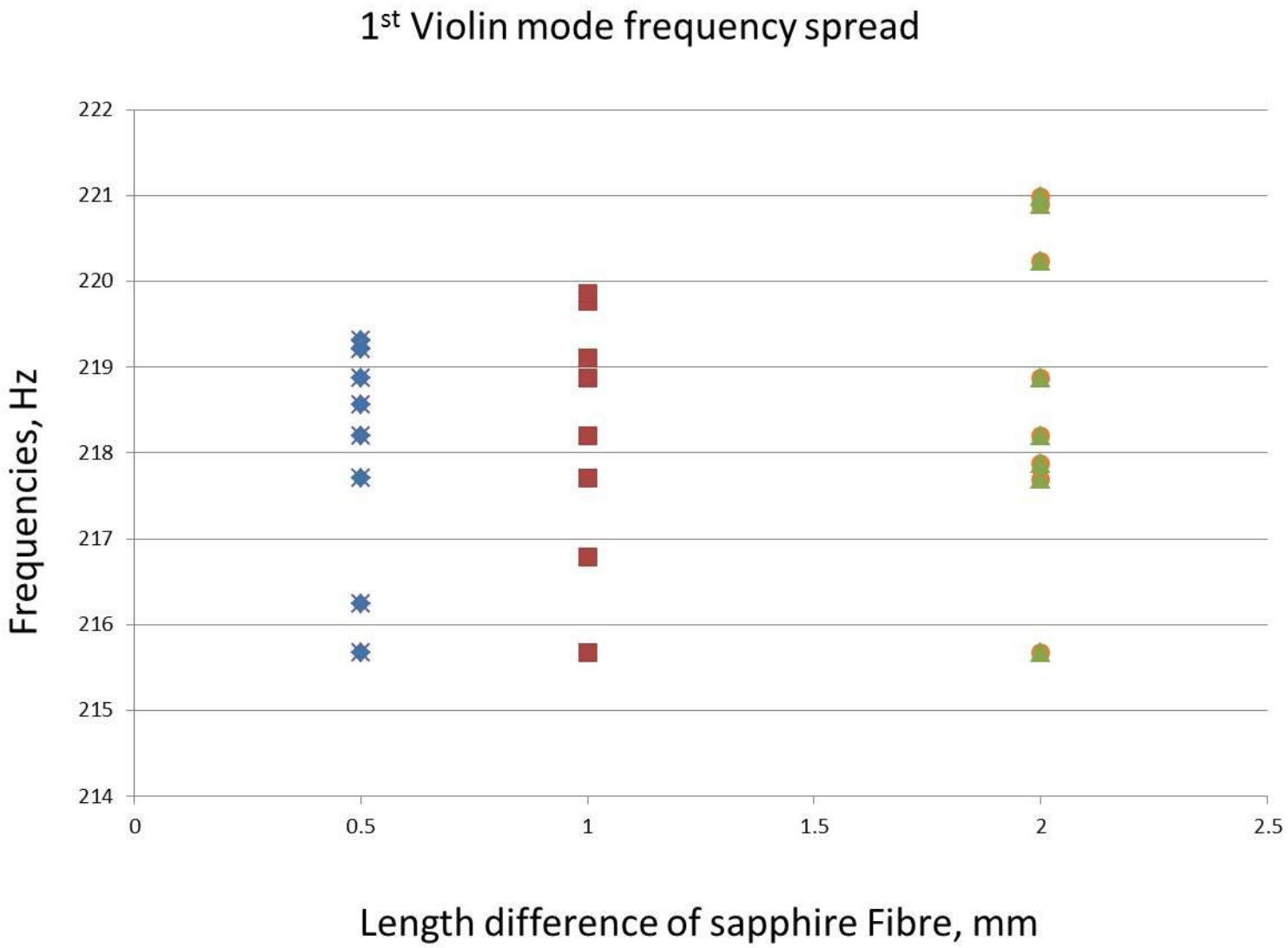

216.8 Hz


217.7 Hz


218.2 Hz


218.9 Hz


219.1 Hz


1st Violin mode frequency spread
Frequencies, Hz
222
221
220
219
218
217
216
215
214
0
0.5
1
1.5
2
2.5
Length difference of sapphire Fibre, mm

Ongoing-future work

- Blade spring design – Target 12-14 Hz
- Mechanical loss and Thermal noise (TN) of the pendulum system (fibres, ears, test mass)
- Thermal noise contribution from blade springs
- Estimation of TN for the bond layers (Indium and HCB)