Risk Reduction Work on Advanced LIGO Suspensions

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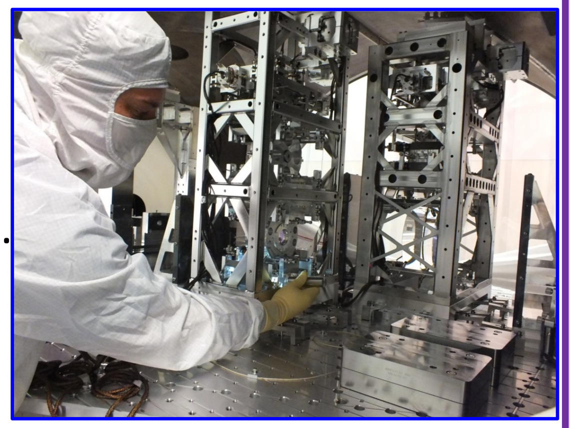
G1400804

1 Introduction

- All Advanced LIGO (aLIGO) suspensions are now installed at both observatories.
- Measurements of dynamical behaviour (mode frequencies, transfer functions, violin mode Qs, actuation levels etc.) show that the suspensions should meet their requirements.
- However some modifications have been proposed as risk reduction steps to improve the performance of aLIGO:
  - ➢ Increased vertical isolation in signal recycling cavity triple suspensions
  - ➢ Revised design of beamsplitter triple suspension for a larger beamsplitter

2 Increased Vertical Isolation for Signal Recycling Cavity (SRC) Suspensions

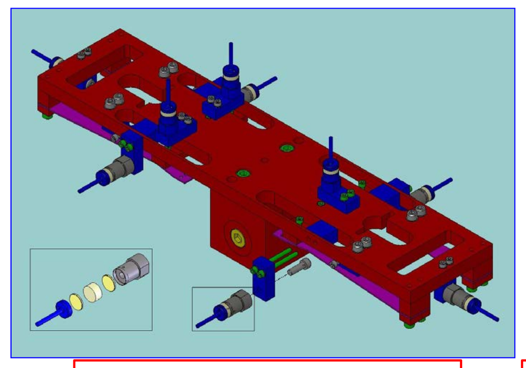
- Noise in the SRC length, coupling into the GW readout through radiation pressure, may be higher than desired
- In particular noise coupling from vertical to horizontal in the three triple suspensions (SRM, SR2, SR3) at their highest vertical mode (28 Hz) is significant
  - ➢ Improve vertical isolation by adding third stage of blades at middle mass: all vertical modes < 10 Hz.
  - ➢ Start with SRM (HAM Small Triple Suspension). Coupling in SRM is larger due to optic pitch



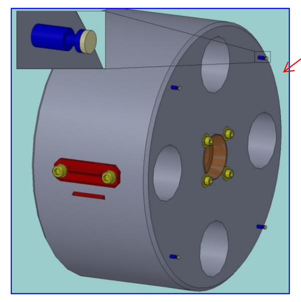
HAM5 Chamber at LLO showing SRM (foreground) and SR3

3 HAM Small Triple Suspension (HSTS) Redesign

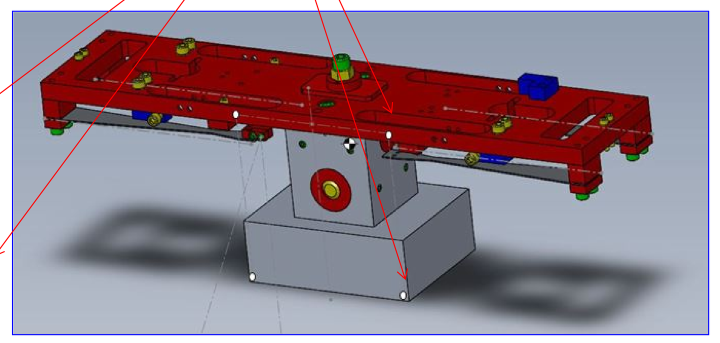
- Primary design considerations: minimise changes and make use of proven design elements
- Consider reusing top mass at middle stage, replacing current cylindrical mass: top mass already incorporates blades
- Extend size vertically to hold magnets for actuation at correct spacing



Current top mass



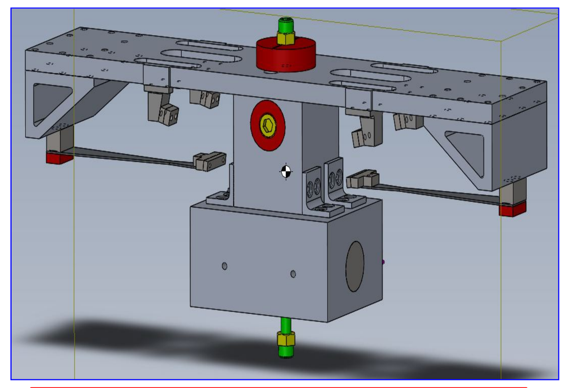
Current middle mass



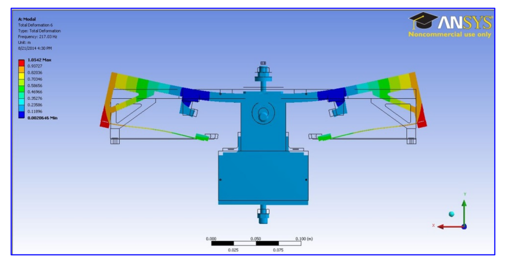
Initial idea for new middle mass

4 Further Development of New HSTS Middle Mass

- Minimise impact on current design and operation of suspension
  - ➢ Use two blades instead of four to keep current wire separation around mirror, and shorten blade length for wire clearance to lower mass
  - ➢ Redistribute mass and change steel to Al to locate centre of mass (CofM) at centre of layout of actuation magnets, keeping overall mass same
  - ➢ Move blades down to below CofM for stability (lowers wire breakoff points)
  - ➢ Re-angle wire clamps as needed
  - ➢ Carry out FEA to check mass and blade internal resonances

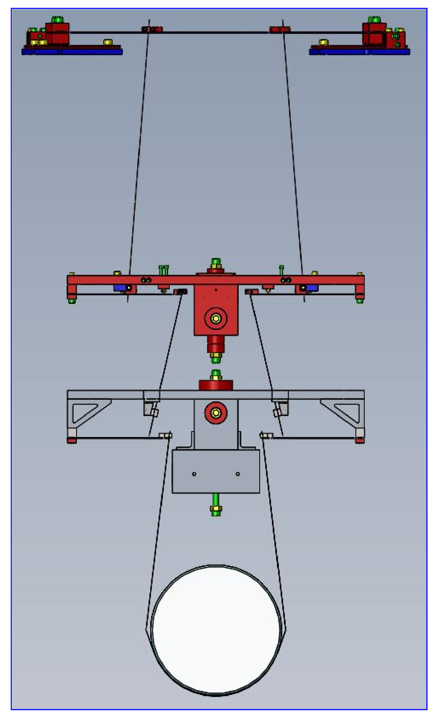


New middle mass design



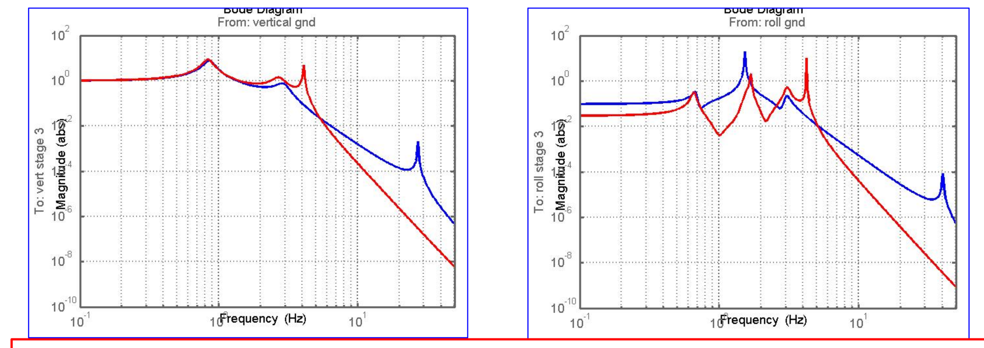
FEA to check stiffness of new design: first resonance ~217 Hz

5 MATLAB Analysis of Redesigned HSTS Suspension



Full triple suspension with new mass

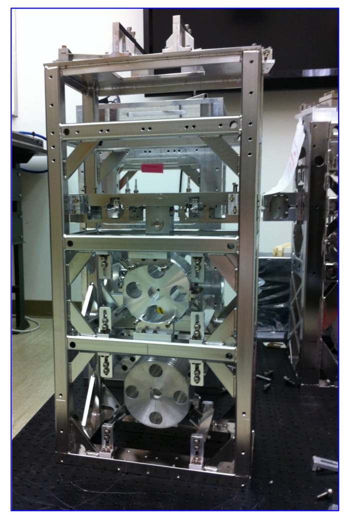
- Compare new dynamical behaviour to that of current suspension:
  - ➢ Add extra blades, change transverse separation of wires and moments of inertia of middle mass
- All transfer functions acceptable: significant differences only in vertical and roll
  - ➢ highest modes now below 10 Hz



Blue is current design, red is new design. Vertical isolation improved: x 7 at 10 Hz, x 100 above ~ 30 Hz.

6 Future Work On HSTS Redesign

- Check basic assembly of new middle mass using 3D printing
- Make metal prototype of mass with blades. Reassemble an existing spare HSTS with new mass: check assembly, alignment, mode frequencies, transfer functions etc
- Incorporate lessons learned into design where possible, based on experience with current HSTSs
- Final design review and potential implementation into aLIGO

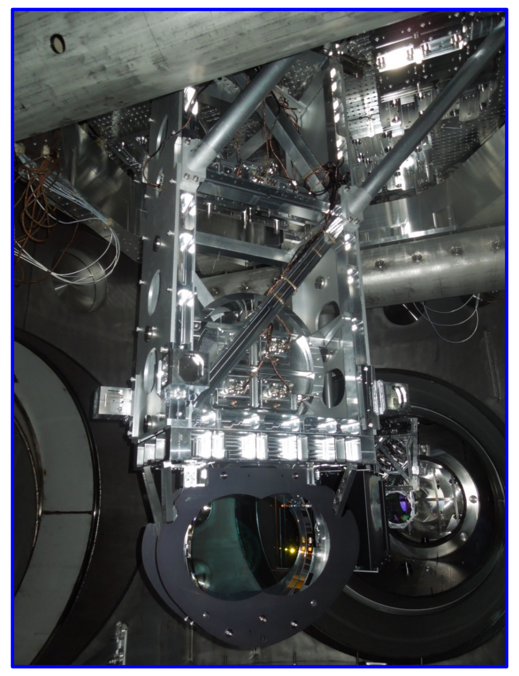


Spare HSTS in Caltech lab

Further details in T1400450 and T1400290

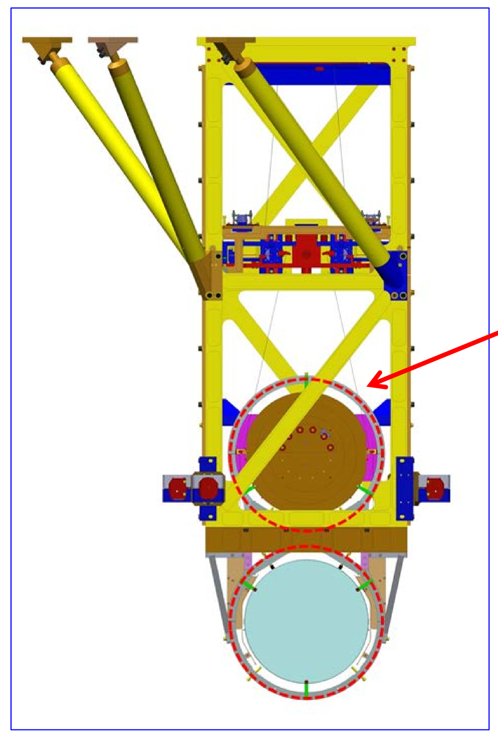
7 Revised Design of Suspension for Larger Beamsplitter (BS)

- Size of beamsplitter (BS) was frozen relatively early: trade-off between clear aperture and manufacturability
- It is the limiting optical aperture in the interferometer
- Enhanced optical simulation indicate the aperture may compromise performance
  - ➢ consider implications on triple suspension design for larger beamsplitter
  - ➢ possible new size 45 cm diameter, thickness TBD (current size 37 cm diam. x 6 cm thick)



Beamsplitter installed at LHO

8 Revised BS Suspension

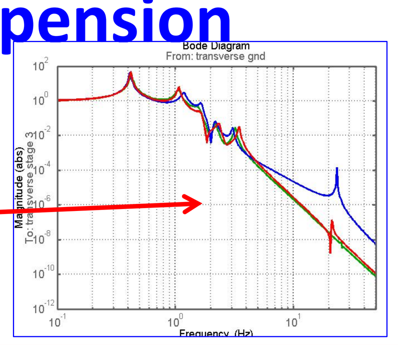


Current design with resized optic and middle mass Indicated in red

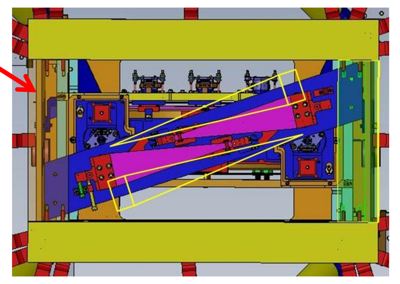
- Implications of larger optic:
  - ➢ All blades need to be redesigned to take heavier mass and maintain isolation
  - ➢ Some structural elements will need enlarged, e.g. "figure of 8" around middle and bottom mass, baffles
- Minimise other changes e.g. keep top mass same, minor changes to box structure as needed
  - ➢ However If new optic is larger than indicated here (45 cm diam.), changes may need to be more significant

9 Future Work on BS Suspension

- Continue MATLAB modeling as design develops
  - ➢ e.g. see strong coupling of highest roll mode into transverse unless middle mass width = optic width
- Investigate fitting larger blades into existing layout, minimise new parts
- After decision on optic size, finalise design work
  - ➢ FEA of revised structure including attachments (baffles etc)
  - ➢ Build full scale mock-up: test fit and assembly
  - ➢ Final design review and potential implementation into aLIGO



Transverse transfer function: green = current design, blue = larger optic, red = larger optic and larger middle mass



Top view of suspension with possible revised blade size and position in yellow

Further details in T1400296