Status and Issues for Quadruple Pendulum Design

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SWG Session

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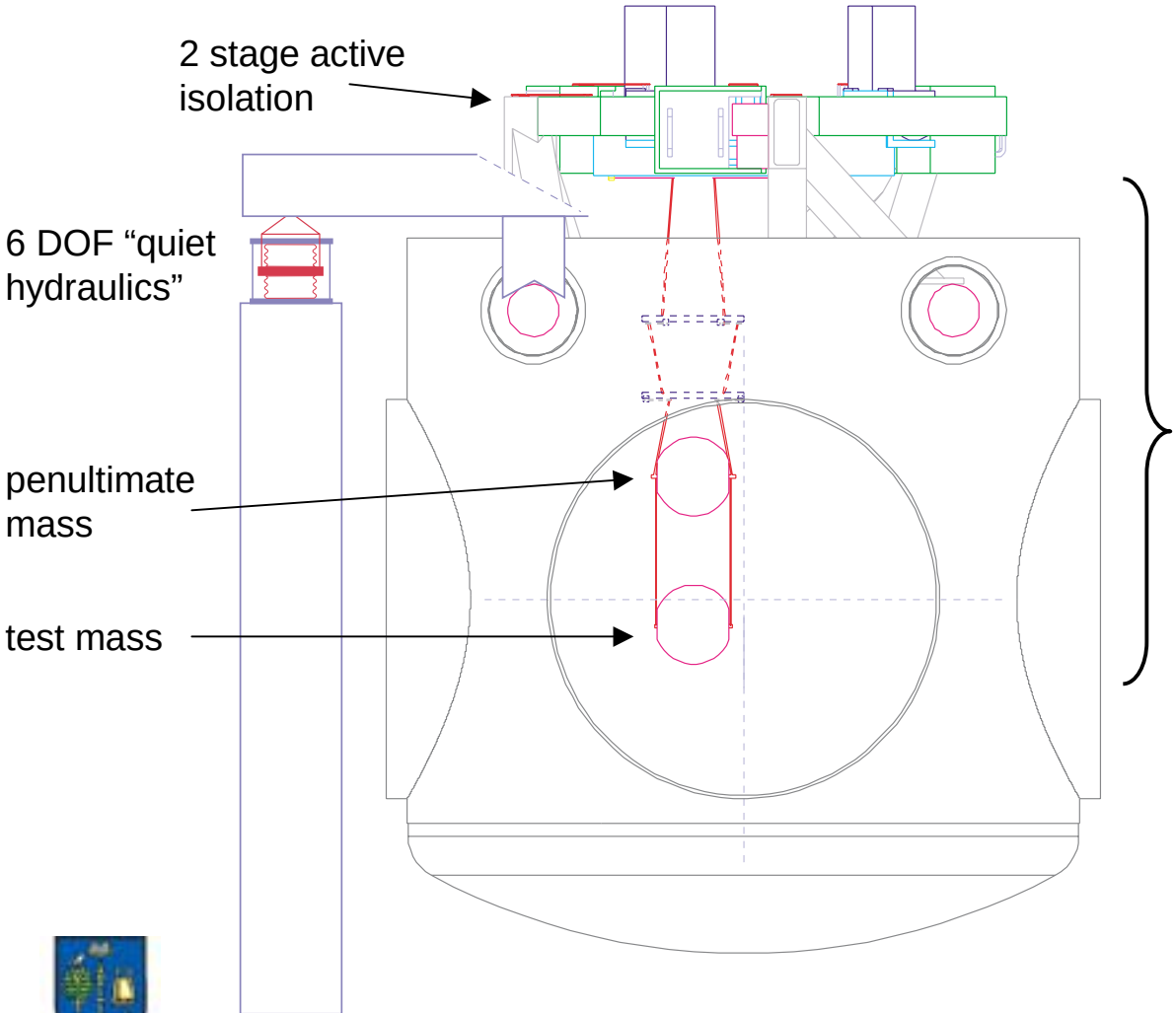
Summary of Topics

- Test mass, penultimate mass + overall mass
- Fibres and bonding
- Damping/local control, noise performance
- Other mirrors

Overall Suspension and Isolation System (BSC Chamber)



quadruple pendulum + reaction chain

Test Mass and Penultimate Mass

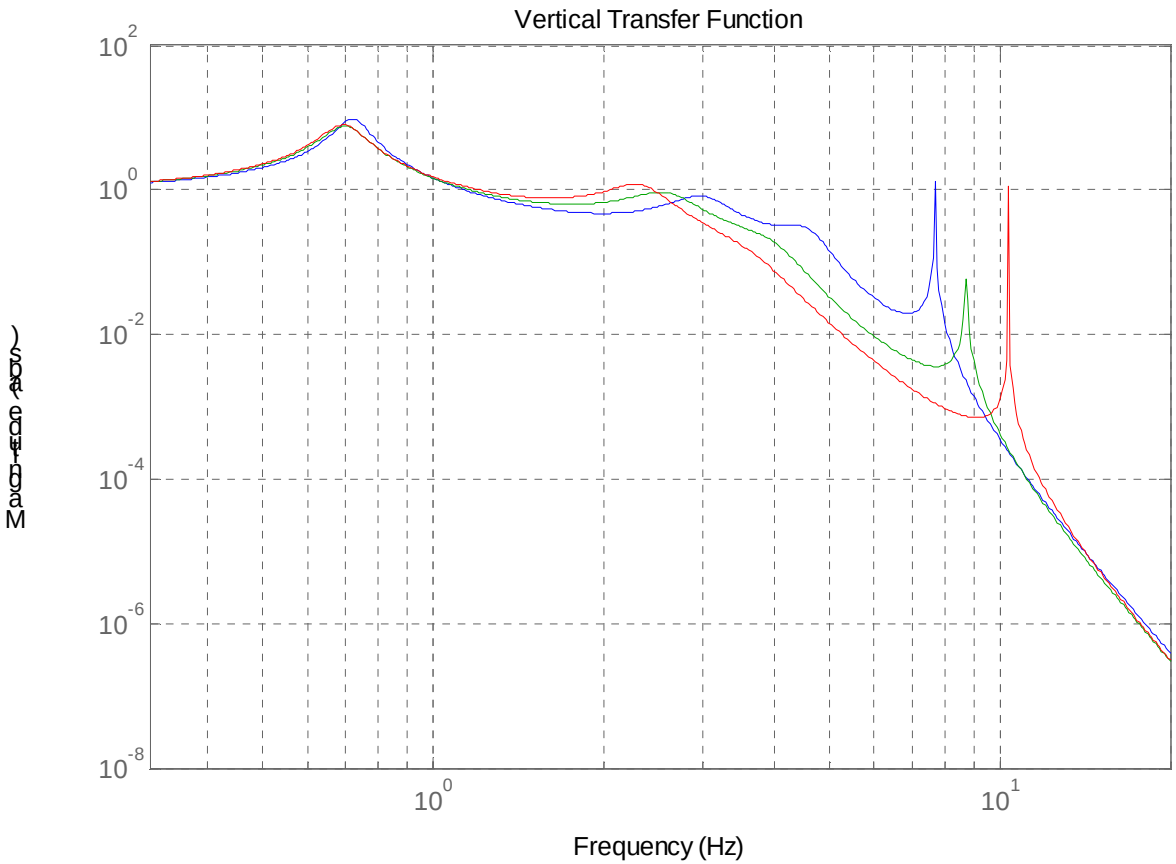
- Test mass
  - baseline: 40 kg sapphire, 31.4 cm (diam) x 13 cm
  - fallback: 40kg silica, 34 cm (diam) x 20 cm
- Penultimate mass
  - original baseline: 72 kg (ultra dense glass)
  - subsequent to low-freq cut-off paper: SF4 (48 kg), sapphire (40 kg) or silica (22 kg) for baseline sapphire test mass
  - recent development (overall mass limit): go for lightest mass

    NB: this would be 22 kg silica with sapphire test mass, *BUT* 40 kg silica with fallback silica test mass, to give same size of penultimate and test masses
- Other masses: rule of thumb - want within factor of 2
  - original baseline: 36 kg, 36 kg
  - recent development (overall mass limit): 22 kg, 22 kg

Summary and Consequences

- Overall suspension:
  - sapphire baseline: masses 22,22,22,40 kg, or 22,22,40,40 (equivalent to fallback situation)
    - Both look feasible. First option is scaled up version of MIT quad prototype – thus experiences of that design are applicable, though footprint now tighter.
  - SF4 (48kg) for penultimate mass too heavy??
  - silica fallback: masses 22,22,40,40 kg
- Consequence - highest vertical mode:
  - ~10.4 Hz for sapphire with silica penultimate mass
  - ~8.7 Hz for sapphire with sapphire penultimate mass, or silica with silica penultimate mass
    (see figure overleaf)

Vertical Modes / Various Models



blue:36,36,72,40 kg
red: 36,36,40,40 kg
green: 36,36,22,40 kg

From: Comparison of Possible Quadruple Suspension Models for Advanced LIGO, NAR 20th May 2002

Fibre and Bonding Issues.

- Choice of ribbon or dumbbell an open issue – research on both in progress, e.g. at Glasgow:
  - ribbon breaking stress 2.9 GPa seen so far for ribbon 1.05mm x 0.12mm (c.f. stress assumed for conceptual design = 770 MPa)
  - ribbon suspension to measure pendulum Q underway
  - construction and testing of heavy glass + sapphire (25cm diam) two stage suspension, with ribbons + bonded ears, to be started soon
- Choice of fibre length an open issue: baseline 60 cm
  - 70 cm gives lower vert. (good) and violin (not so good) modes
  - consequences for manufacturability, overall length (installation and accommodation in BSC chambers)- fit is tight!

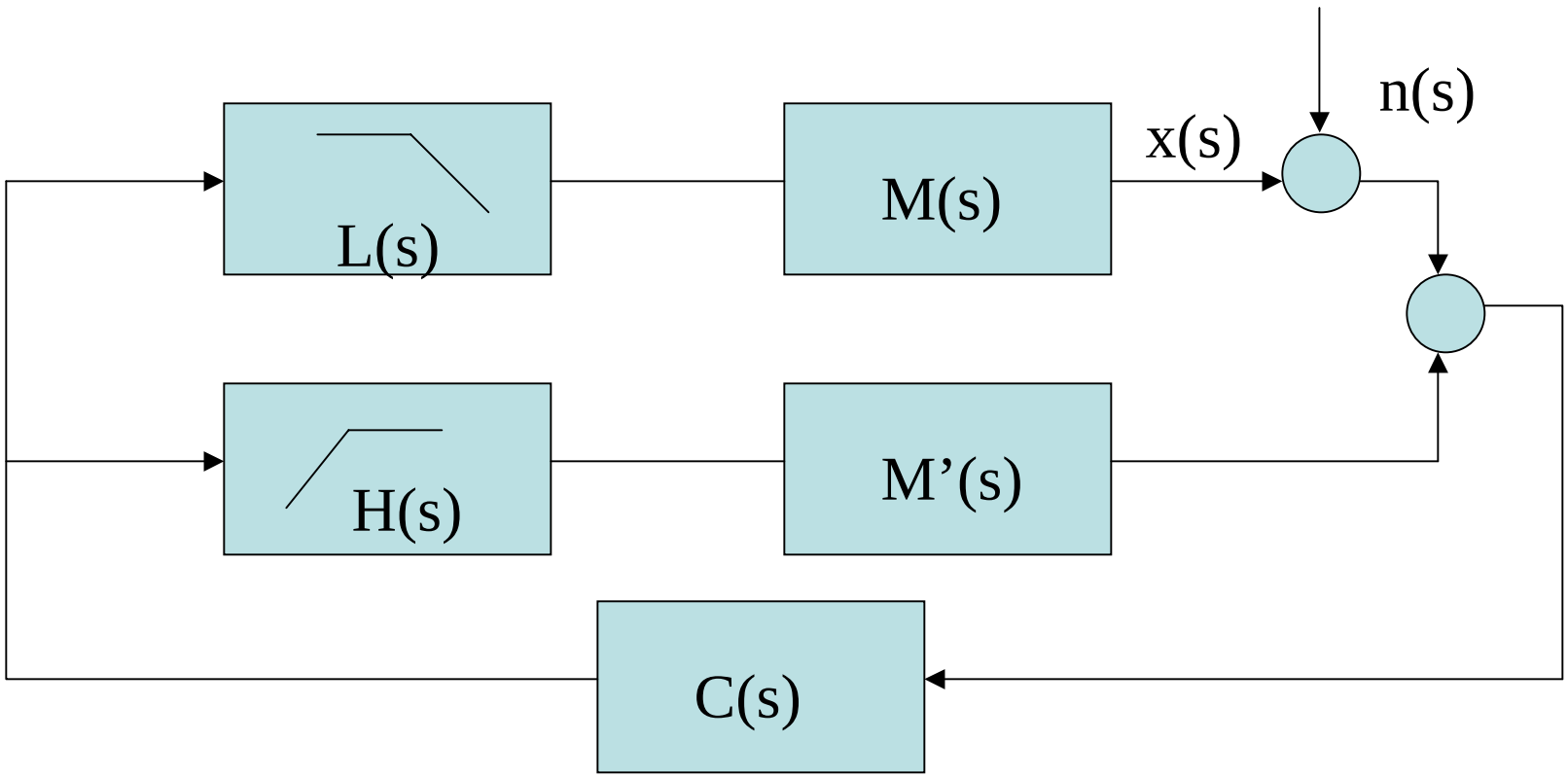
  *******Suggest fix at 60 cm*******
- Bonding: silica/sapphire and silica/SF4 under ongoing investigations. Recent results from Caltech mixed for SF4 bonds (see Willems presentation)

Damping/Local Control

- Still an outstanding issue (see also Willems presentation)
- Possible solutions for 10 Hz requirement for test masses (10^{-19} m/$\sqrt{}$ Hz)
  - For longitudinal, yaw and pitch – use global control signals to take over once interferometer locked, and turn down local gain
  - For other modes?
    - use local control and turn down sufficiently if can allow higher Qs once in operation
    - develop better sensors……..
    - investigate double loop “smart control” scheme (see next slide) – as demonstrated by Passuello and Losurdo in VIRGO
    - eddy current damping OK for triples/ challenging for quad unless can tolerate higher Qs

Double Loop Scheme
(ref Passuello and Losurdo)

Basic idea: two branches together equivalent to M - but noisy high freq. part of control signal is passed through simulation of mechanics and hence not fedback to actuator



M = real mechanics, M' = virtual mechanics, M = M'. L and H = low and high pass filters, L + H = 1. C = compensator, x = signal, n = sensor noise.

Finally - Other Mirrors

- Designs are required for
  - Beamsplitter: 35 cm (diam) x 6 cm, 12.7 kg
  - Folding mirror: 35 cm (diam) x 11.8 cm, 25 kg
  - Compensation plate: ???
- Points to note
  - Aspect ratio of splitter more extreme than any previous designs
  - Large diameters push envelope of footprint
  - Isolation requirements for splitter, folding mirror (2×10^{-17} m/$\sqrt{}$ Hz at 10 Hz) not as severe as for test masses – triple suspension might be feasible. This would ease footprint (lengthwise)