Violin mode damping for the ETM/ITM QUAD suspensions

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Requirements

- recovery after disturbance
  - natural Q ~10^{10}
  - freq. ~ n.400 Hz
  - natural damping time several days
  - could need 10 or more times this to recover
  - want ~1000 times faster damping Q~few million
- controllability
  - want LSC bandwidth >~100 Hz
  - violin modes affect TM and PM feedback
  - helpful if notches do not need to be too deep
- if first requirement is met second is easily met

Response (T050267-00-K)

- Model
  - Mark Barton's SUS toolkit + global control model
  - SUS model
    - 5-bead violin strings for last stage incl. stiffness
    - otherwise rather complete quad model
    - export state-space to MATLAB
    - extend to ribbons by factoring in dilution factor
  - LSC model
    - crude, but with the essential elements
    - not meant to be used to answer actuator force questions
    - enables tests of active and passive damping
  - thermal noise model (Geppo + material developed from Gossler)
    - for passive damping of violin modes
    - extrapolates GEO results

Passive damping

- Amorphous Teflon?
  - ribbons are under more tension than GEO fibres, and noise requirements are much more severe
  - not possible to reach target Qs (by far)
- PM tuned dampers
  - many needed (4 x ~4 modes per suspension)
  - must be rather high Q to achieve efficient coupling (40kg mass) probably drift off resonance with temperature/time
  - not promising

Active damping

- Goal
  - to damp the first few modes of each ribbon (up to ~1.6 kHz)
  - higher modes couple less and are much less likely to be excited
    - implies limit for stiffness of stops so that high frequency jarring of the suspension is minimised
    - structure is quite soft, as are stops, so it seems unlikely that modes above 1.6 kHz should be excited
    - needs some care in design
- Feedback
  - PM
    - actuators already fitted
    - ribbon stiffness makes good coupling
  - ribbons
    - new actuators needed
    - could be co-located to damp more modes

Active damping 2

- Sensing location
  - PM
    - needs low noise sensor (100 dB lower than below)
    - hard to make filter since sensor and actuator see 4 ribbons and there is only one signal path
  - Ribbon
    - relatively relaxed noise target (possibly 10^{-11} m/Hz$^{1/2}$ but TBD)
    - 4 individual and relatively simple filters can be employed (e.g. 4 complex poles and zeros plus one real pole and zero sufficed in the MATLAB model)

Active damping 3

- Sensing location
  - sensor should be close top of ribbon (to allow max. number of modes to be damped)
  - need to have 1 mm range in 2D (unknown ribbon position)
  - optical?
    - possible but complex and perhaps hard to align, perhaps heavy
  - electrostatic?
    - possible (acc. Nick Lockerbie and elementary model), light, easy to align
    - design work to start soon
- Costs (for proposed ribbon sensing PM feedback)
  - increased number of ADC channels (4/quad)
  - additional wiring through SEI etc. 4 signals/quad