HAM Seismic Attenuation System for LIGO and ad-LIGO

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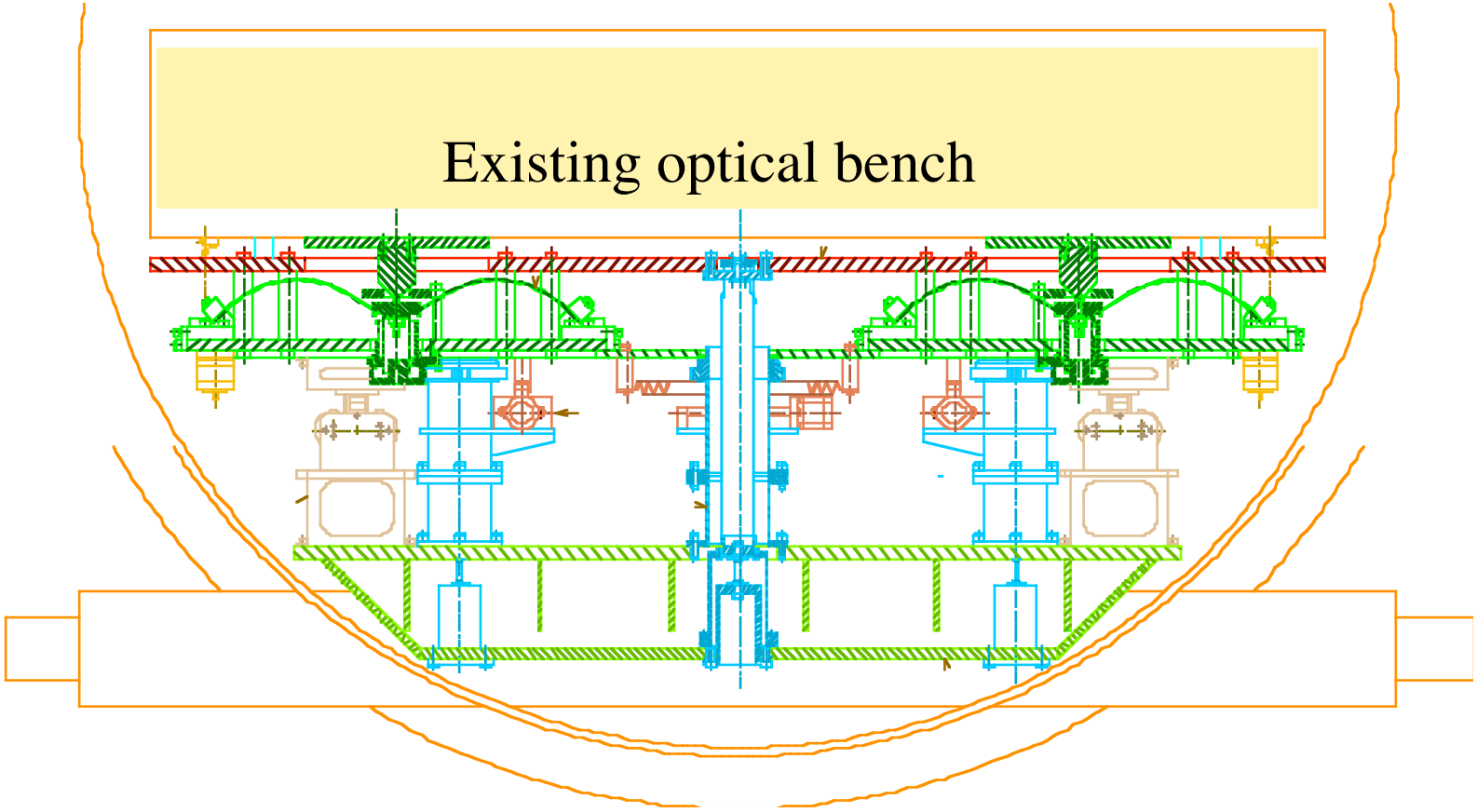
HAM SAS BASIC CHARACTERISTICS

- Simplest possible seismic attenuation system.
- One single stage of passive attenuation
- Broadband attenuation performance ~60 dB
- Satisfying OMC requirements in present LIGO and Adv-LIGO seismic isolation requirements for all HAM chambers
- Earthquake immunity (1 cm excursion)
- Tidal correction and << μrad dynamic alignment
- Thermal stability

HAM SAS BASIC CHARACTERISTICS

- As inexpensive as possible
  - ~1/3 of active baseline adv-LIGO SEI cost
  - less control complexity
  - Can replace stacks without replacing present optical tables
- Upgradeable to active attenuation as reserve of attenuation power
- HAM SAS technology is homologous to the multiple pendulum suspension's forming
  - more homogeneous seismic attenuation and mirror suspension system
- Can be implemented in either HAMs and BSCs

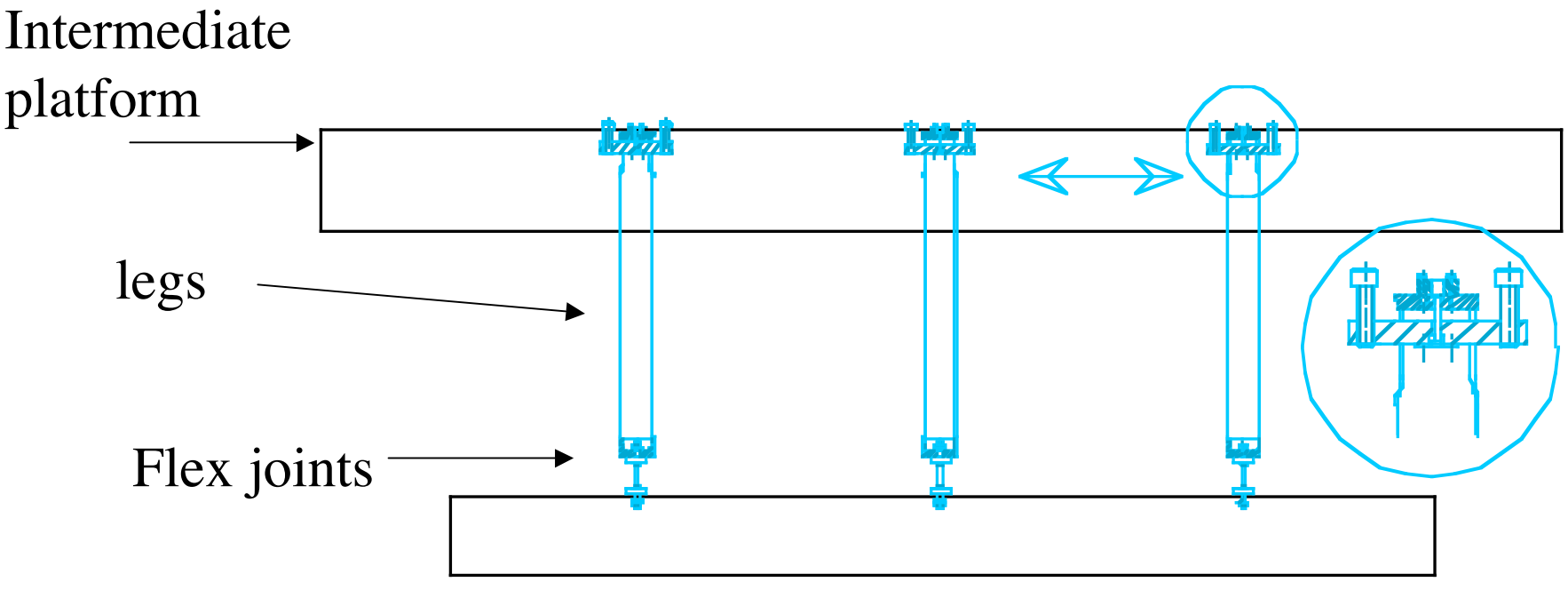
HAM implementation



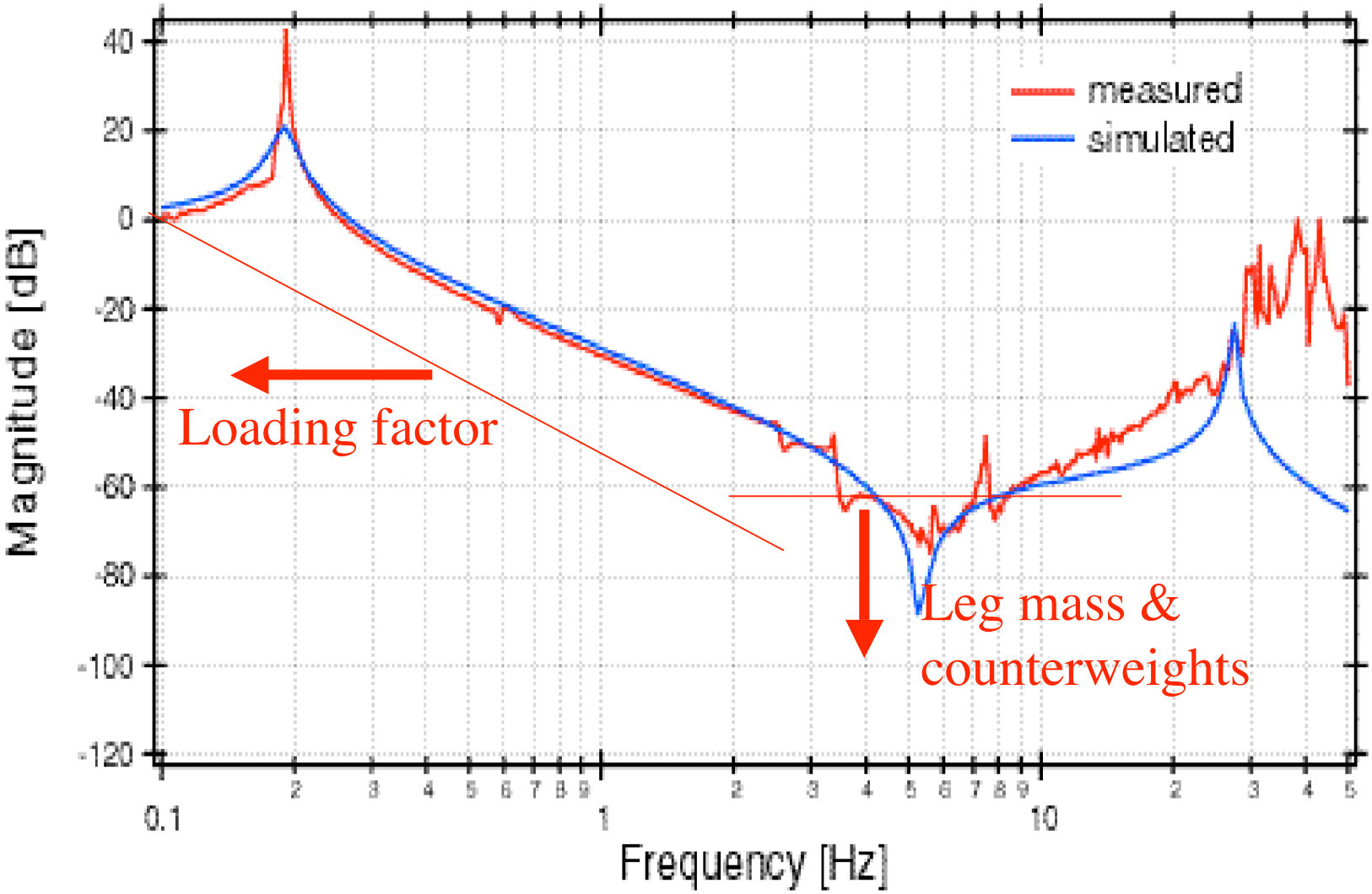
The three components of HAM-SAS

- Horizontal attenuation
  Inverted pendula
- Vertical attenuation
  GAS springs
- Positioning/pointing
  LVDT and actuators

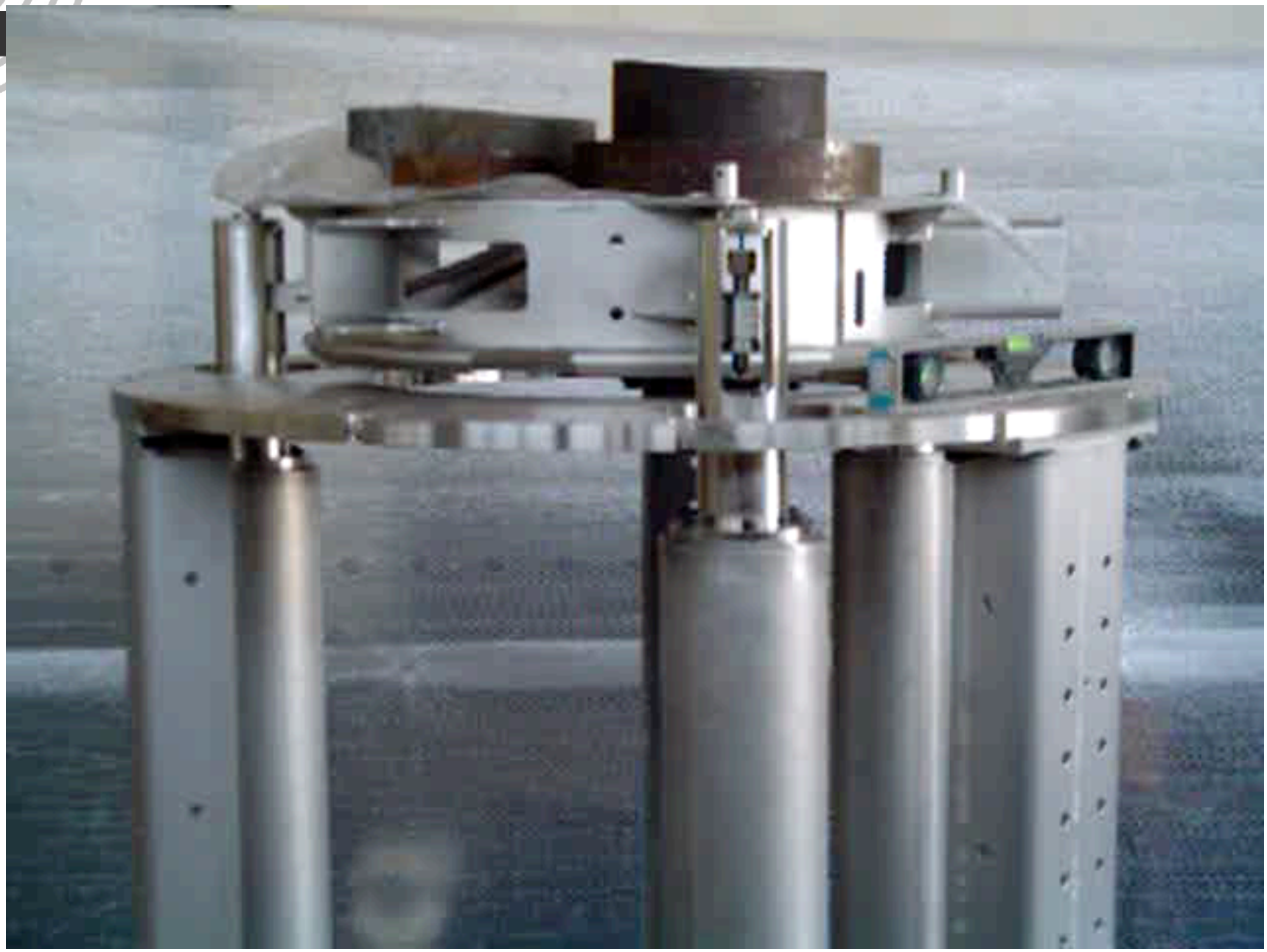
Horizontal direction, x, y, phi the IPs



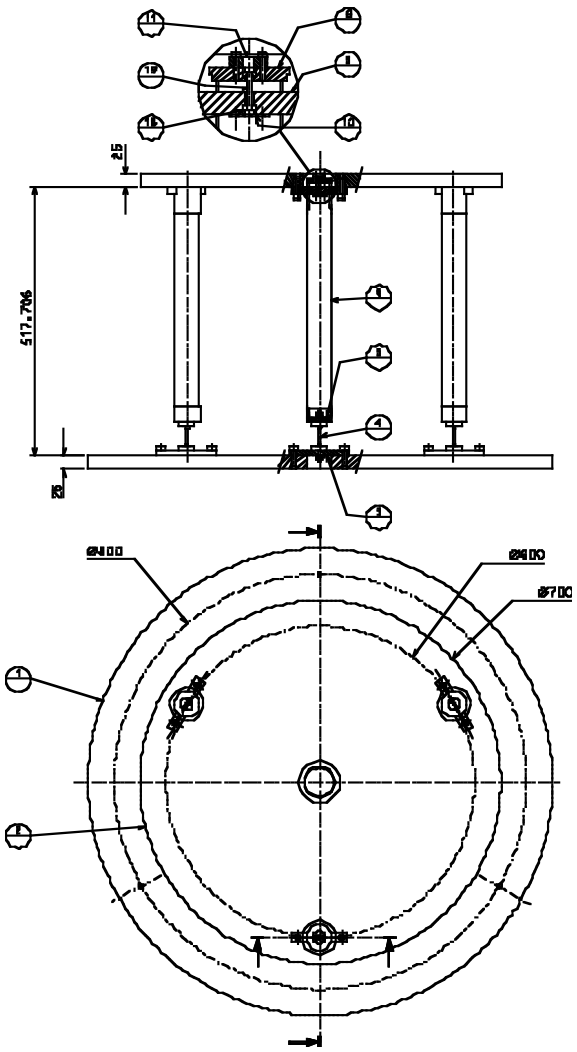
Typical IP Horizontal performance



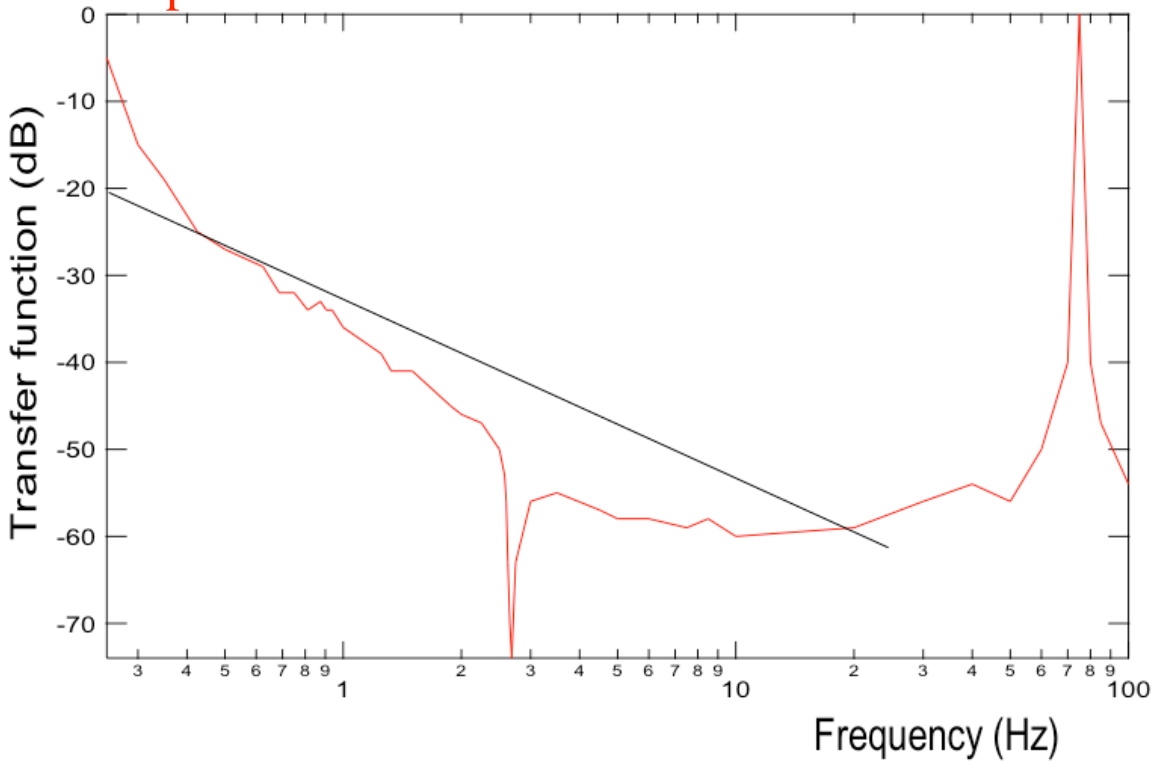
Shaker shaking tower



HAM IP prototype tests

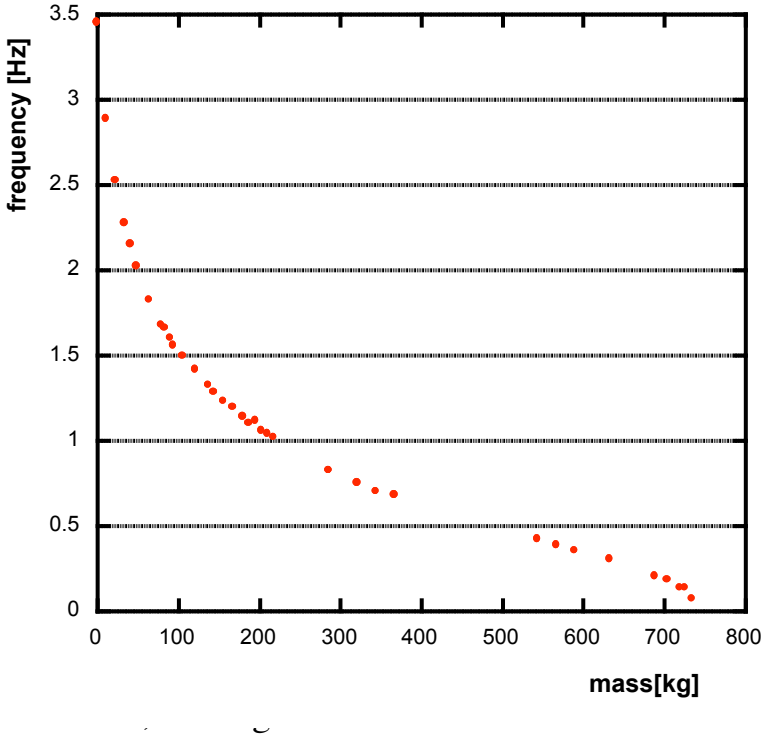


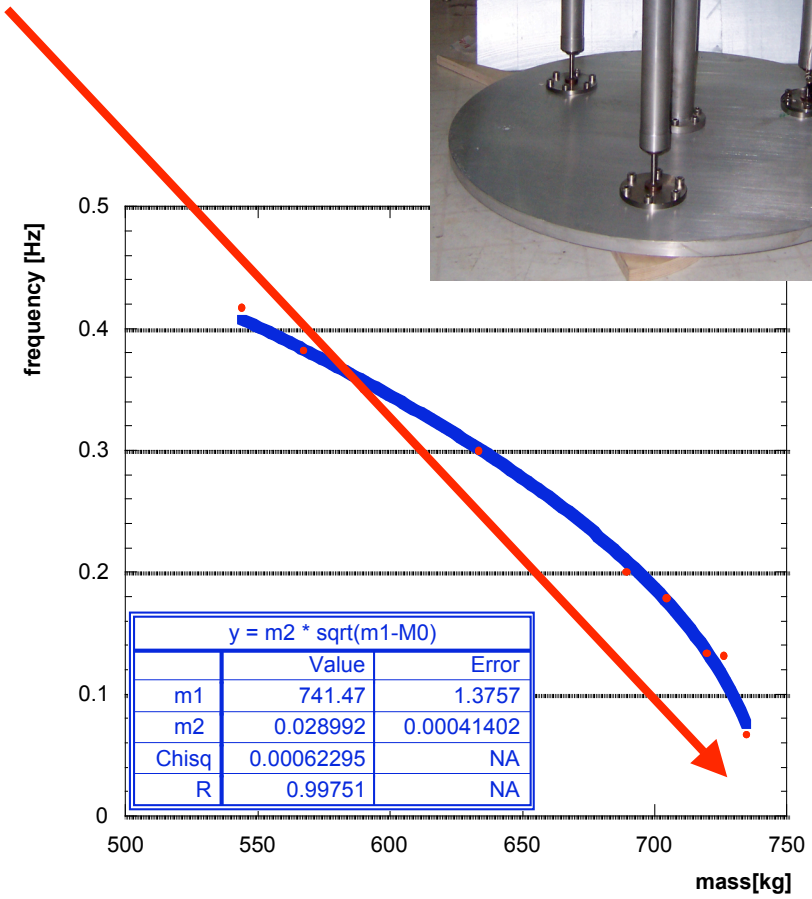
- Preliminary test results
- 60 dB achieved without CounterWeight
- 1/8 payload (8 times better at full payload)
- Further improvement with CW
- >80 dB potential!



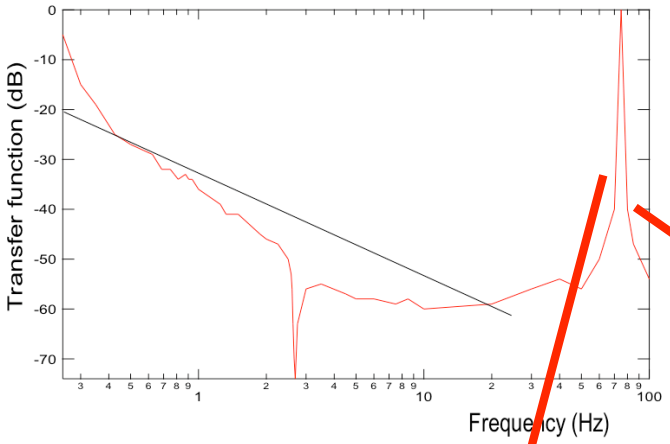
Frequency/Load curve

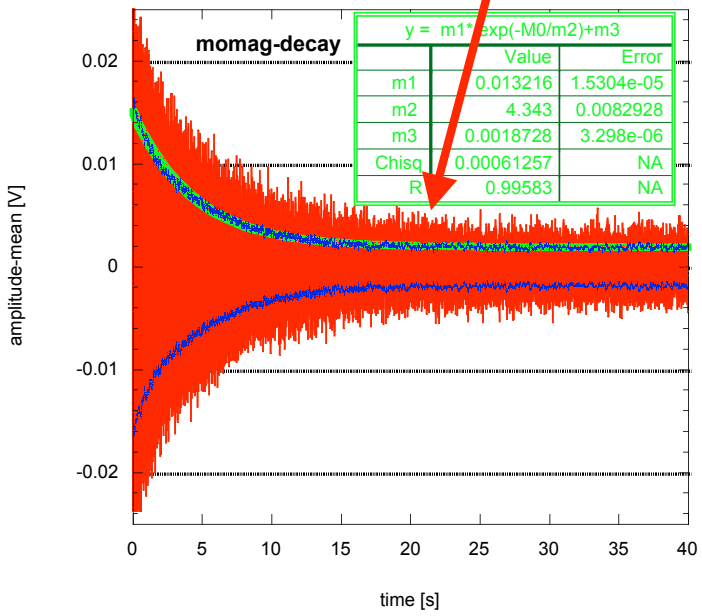
<30 mHz tune on stable ground





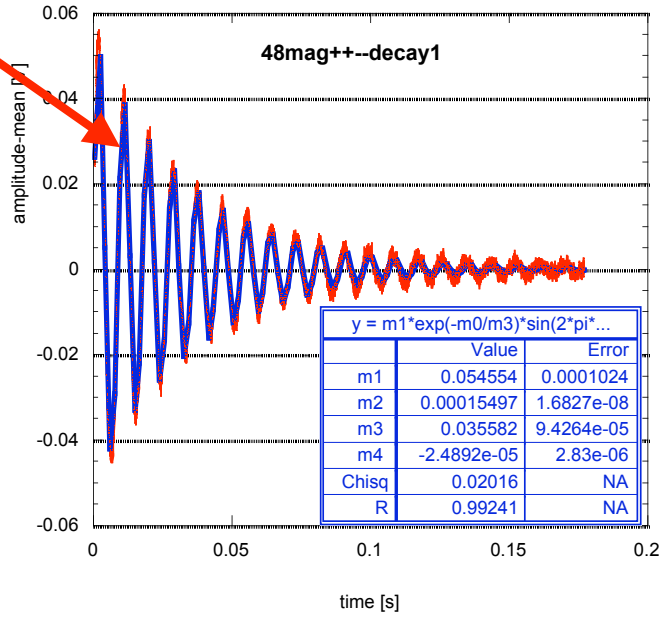
Eddy current resonence dampers



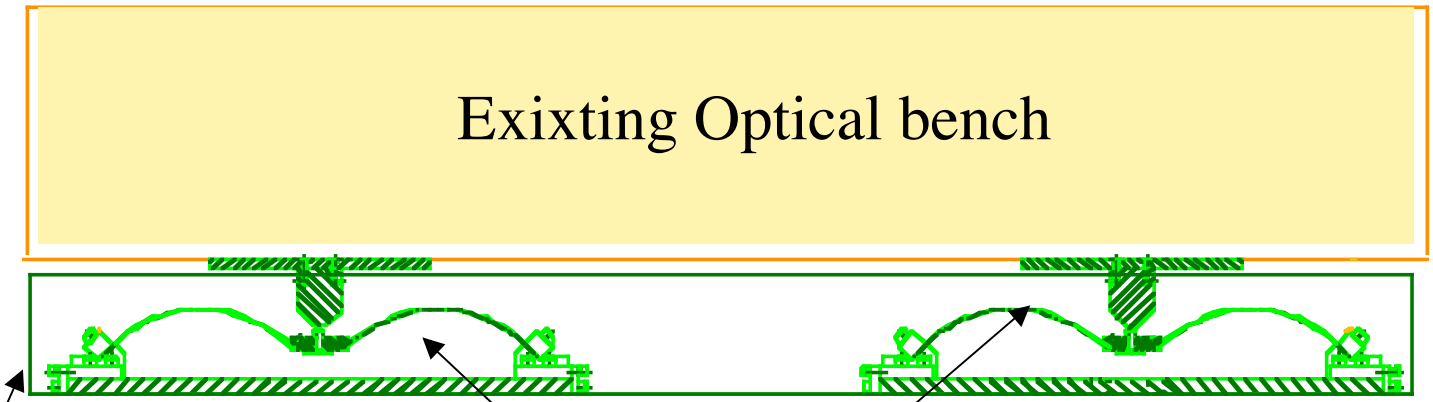


<--Without
τ = 4.3 s

With -->
τ = 35 ms

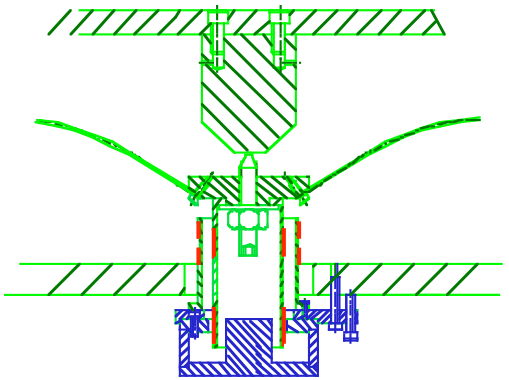


Vertical direction, the GAS springs

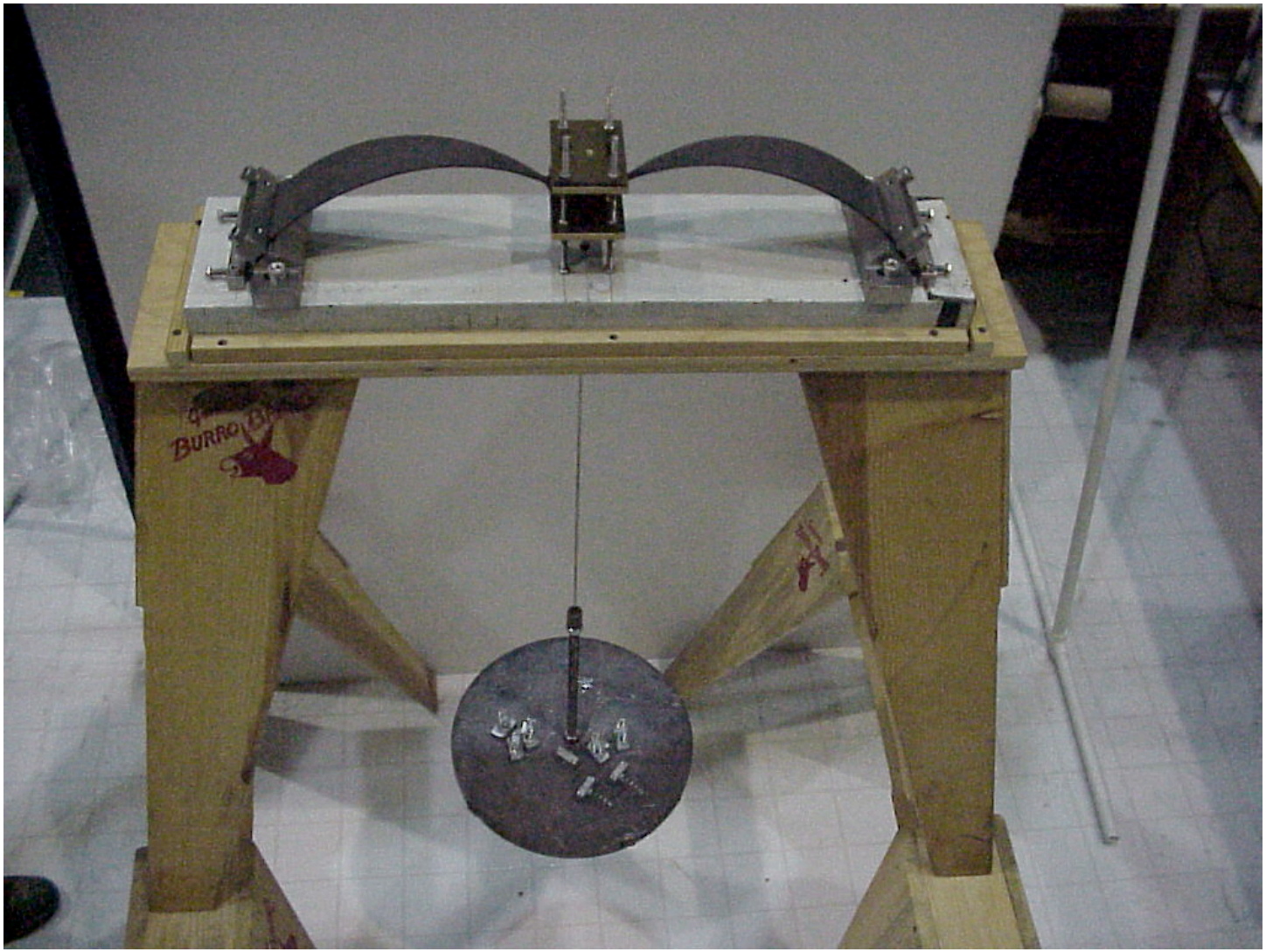


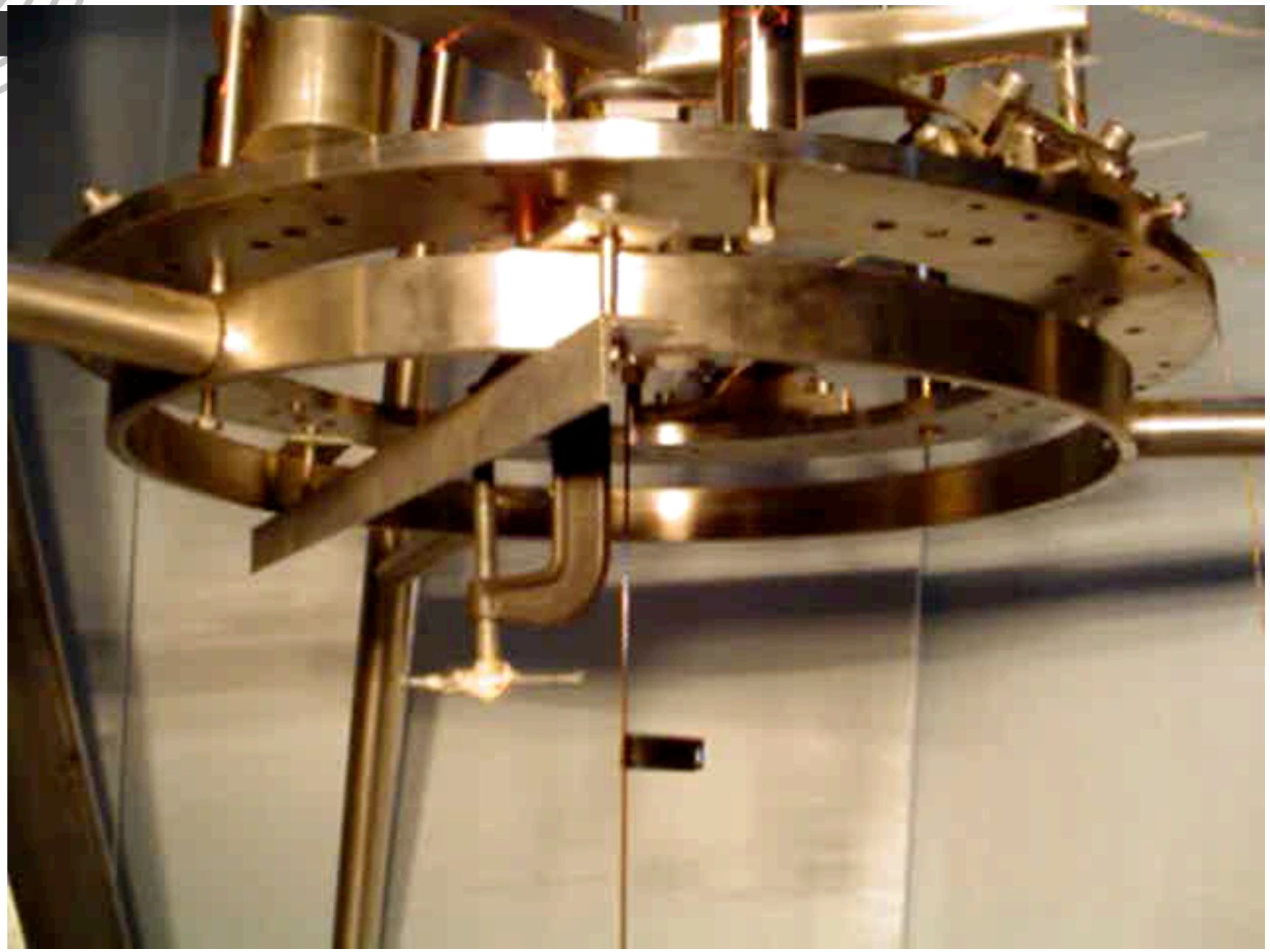
Intermediate platform

GAS springs

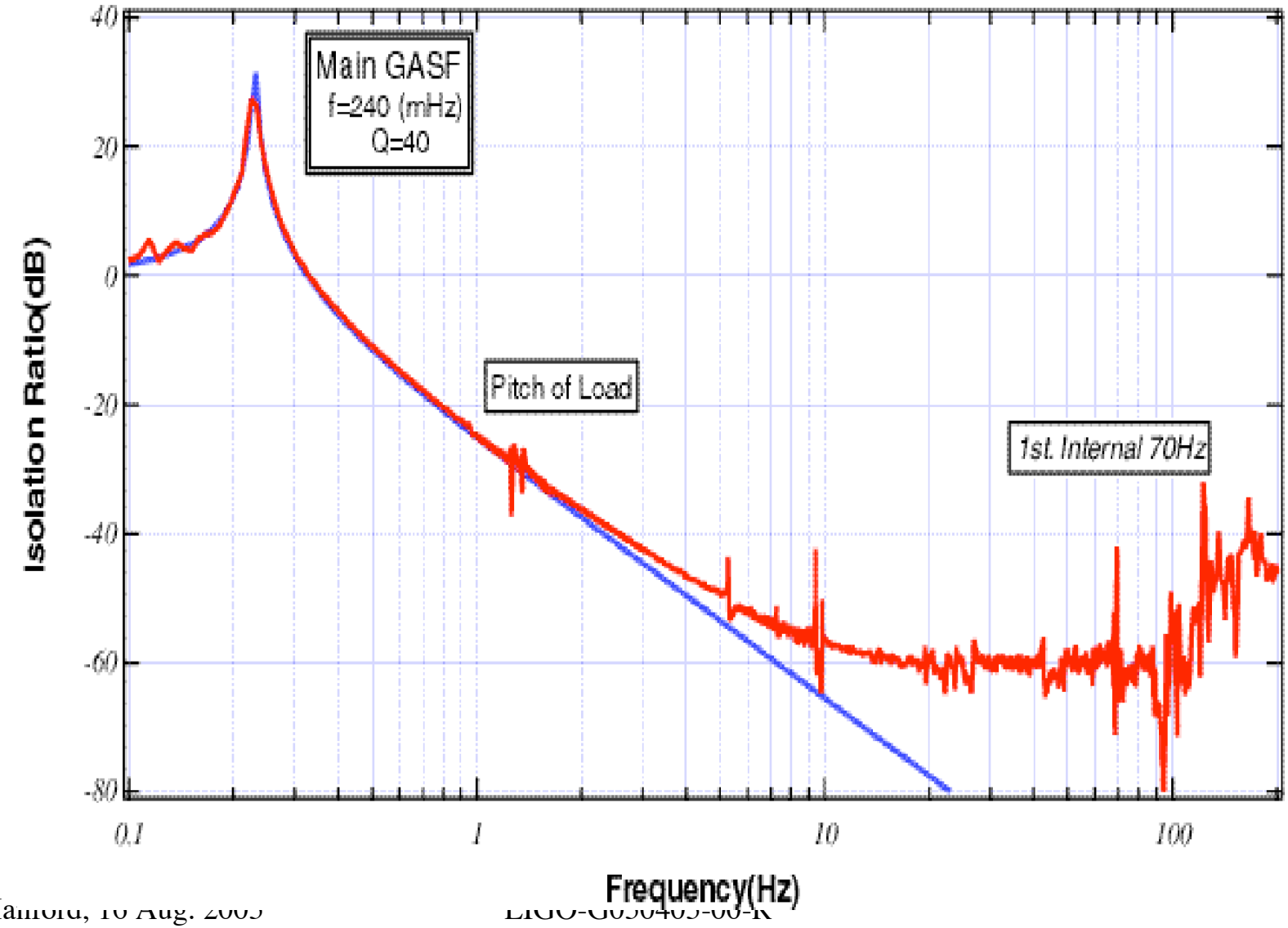


Vertical direction SAS





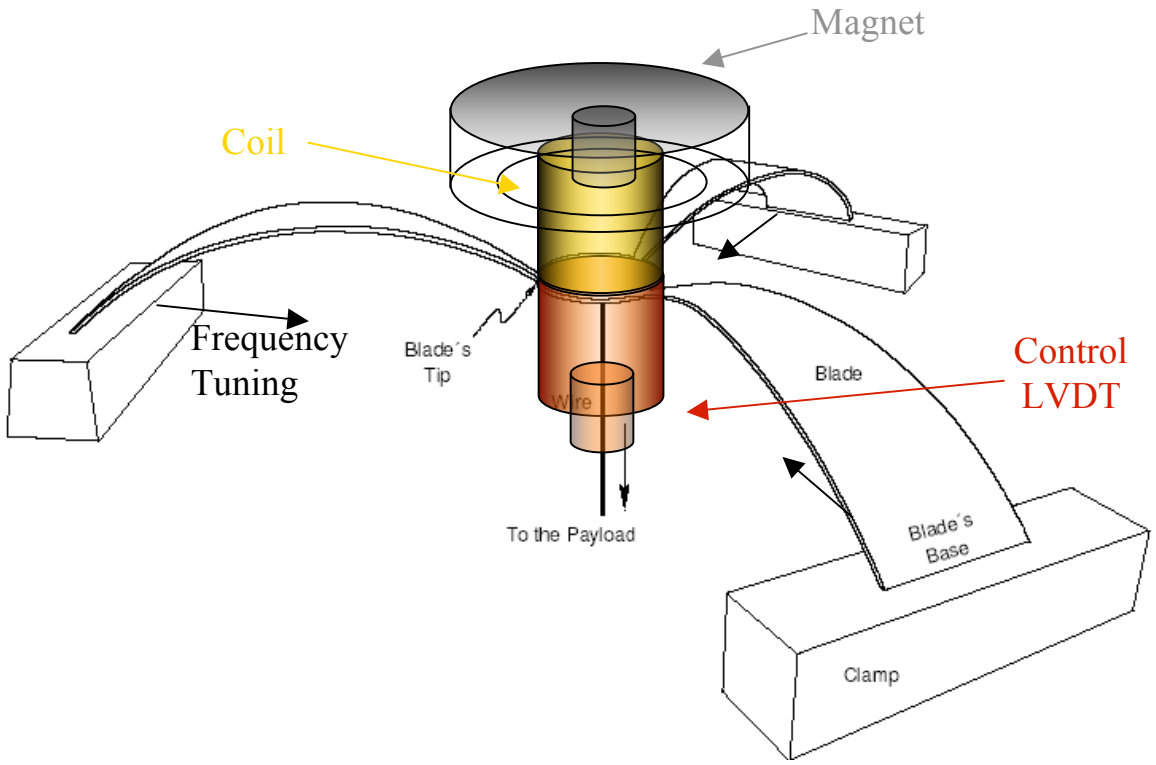
Passive vertical performance

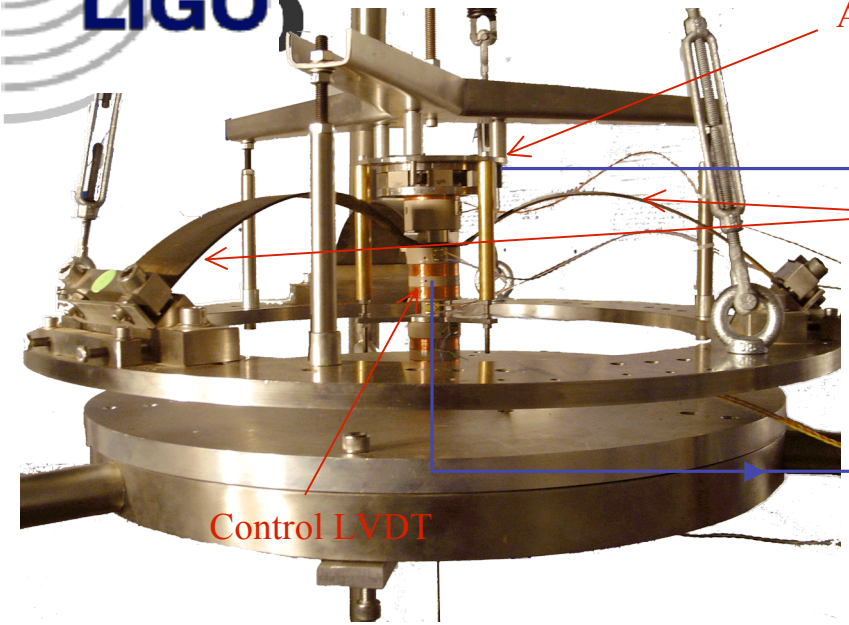


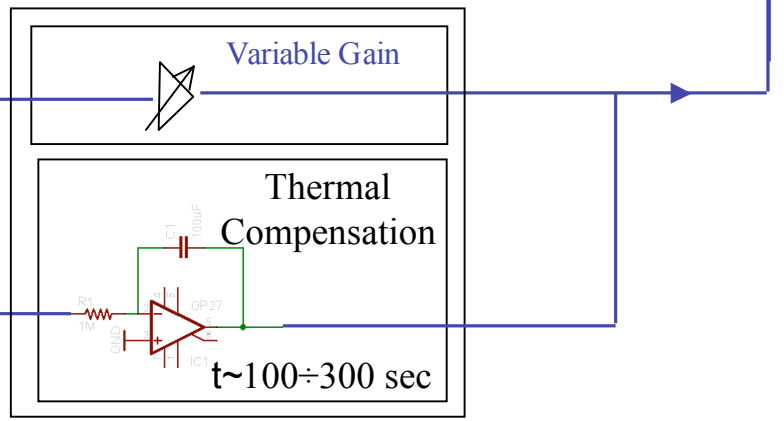
Passive vertical performance

- There is a practical low frequency limit (~200 mHz)for purely mechanical GAS spring resonance due to material properties (hysteresis)
- The limit is ≥ 0.1 Hz resonance frequency
- <30 mHz resonance with E.M. springs

Existing MGAS Spring







- LVDT
- Variable Gain
- Amplificator-Voice Coil

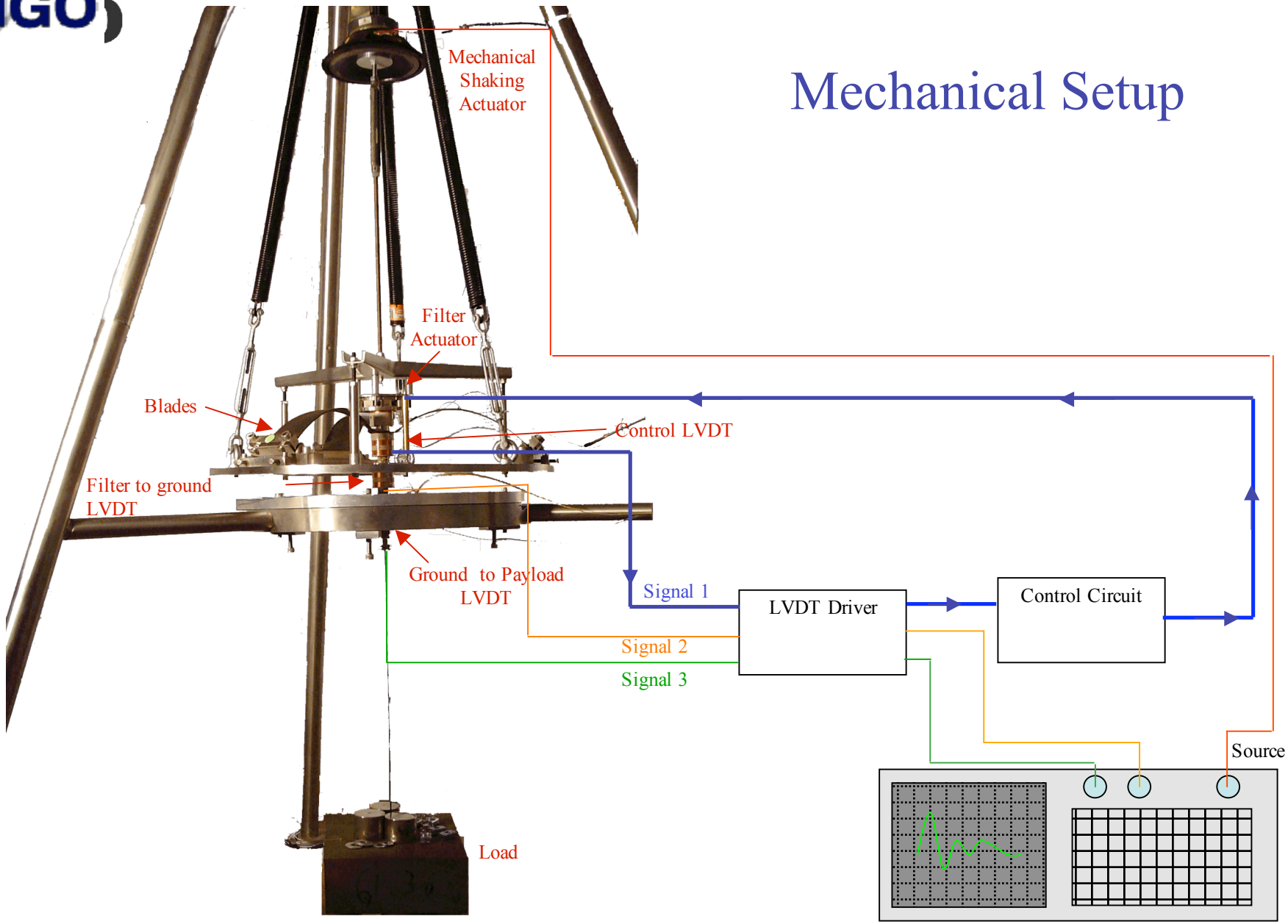
→ Tunable spring in parallel with MGAS spring

(Set Point Integrator → Thermal Drift Correction)

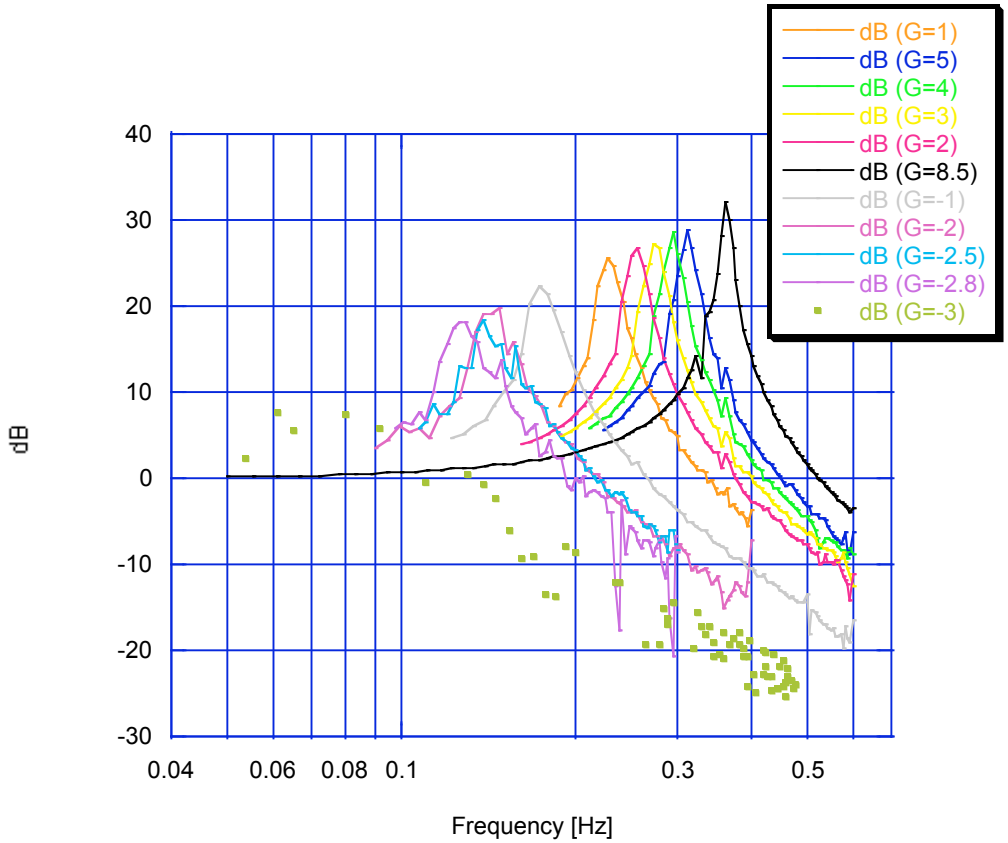
MGAS already neutralize > 90% of cantilever spring stiffness

Circuit corrects the last few per cent of stiffness and stabilizes performance

Mechanical Setup



Transfer Function with Different Gain values



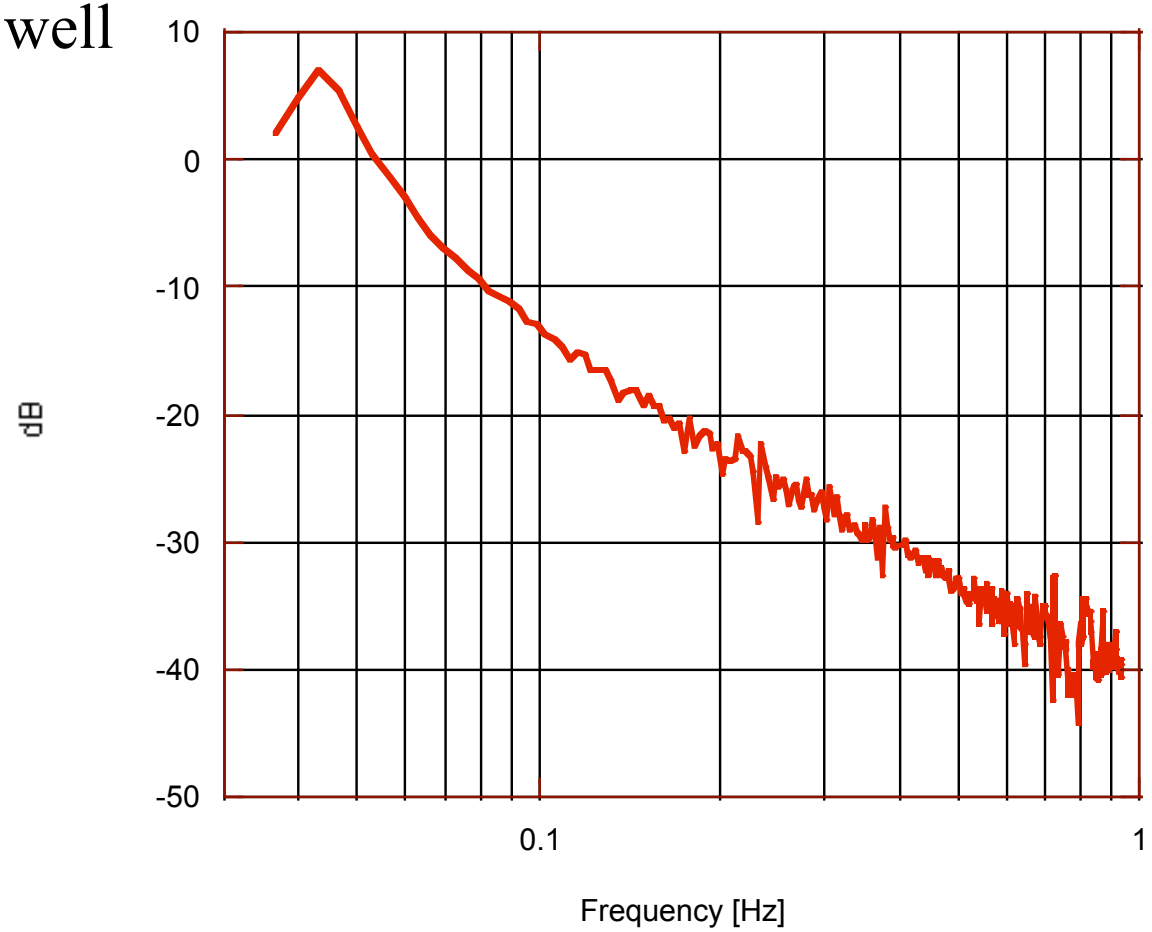
Lowering the system stiffness

As the Transfer Function is shifted to lower frequencies,

The Q factor decreases

Vertical attenuation

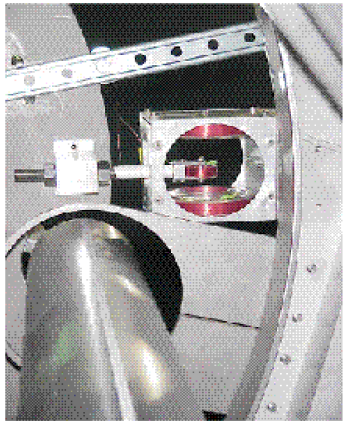
- This technology allows the introduction of attenuation factors as large as one thousand for frequencies above 1 Hertz for LF-GW-ID
- Sizeable attenuation at the micro seismic peak at 150 mHz can be obtained as well

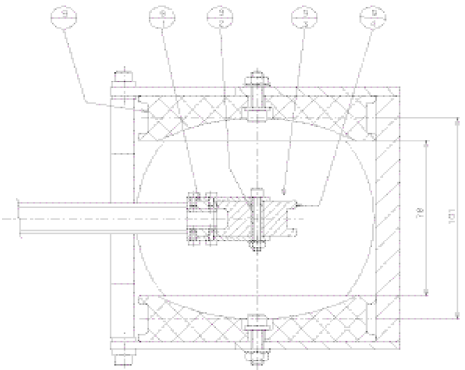


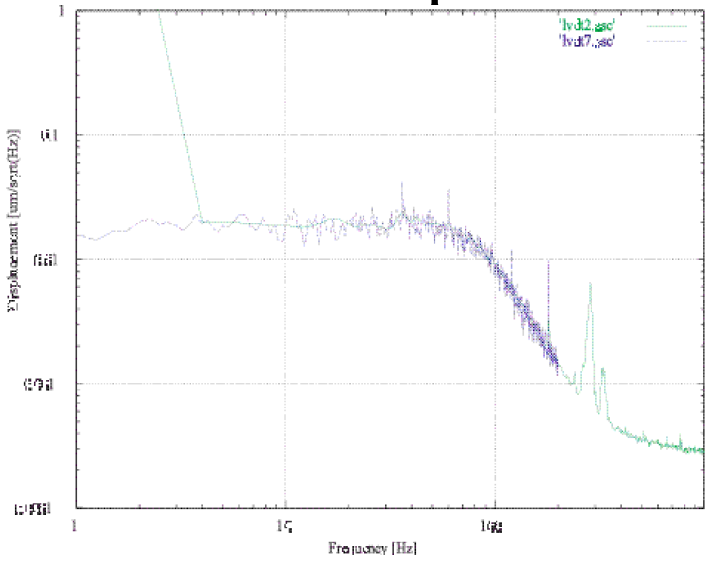
Static and dynamic

MICRO POSITIONING AND POINTING

- LVDT for local nanometer positioning memory
- Voice coil actuator dynamic controls
- Position and alignment controls < 30 mHz
- Remotely actuated Parasitic springs
  null standing currents in actuators
- Micro/milli Watt in-vacuum power
  dissipation



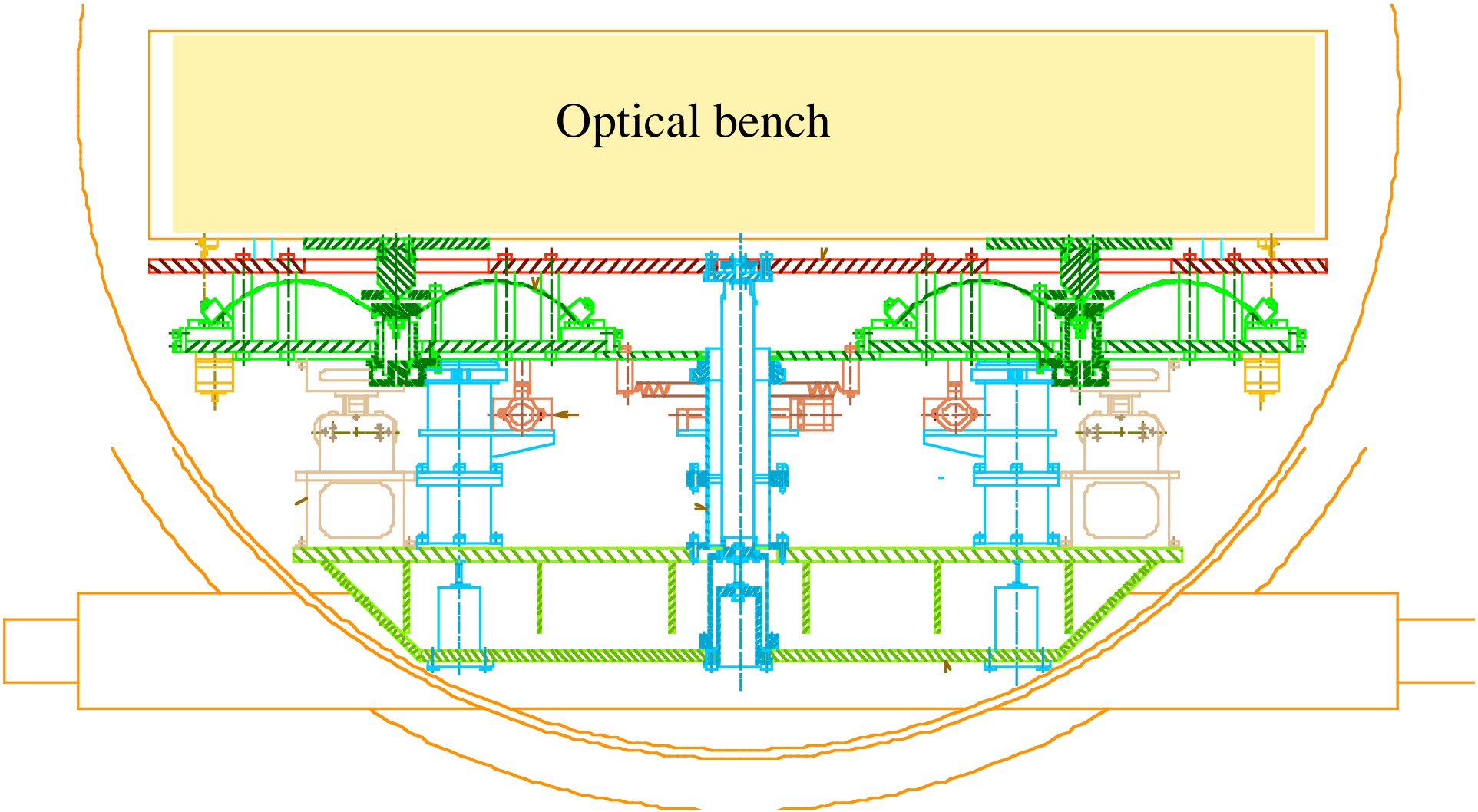




Positioning and pointing

- LVDT, nanometer resolution position sensors, read position and orientation
  - or suggest changes of ballast to regenerate the previous balance after interventions
- Low power, UHV compatible voice coils are suitable actuators to deal with tidal and thermal position changes
- Position controls of the actuators to maintain the table alignment limited below 30 mHz
  - sensors and actuators are available for active attenuation if deemed necessary

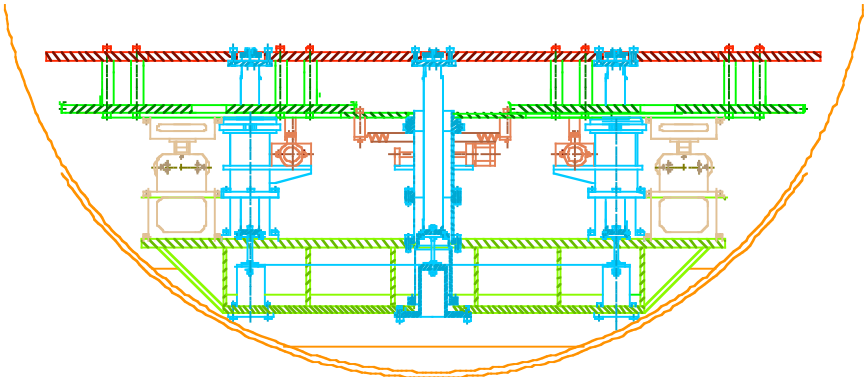
Complete HAM SAS design

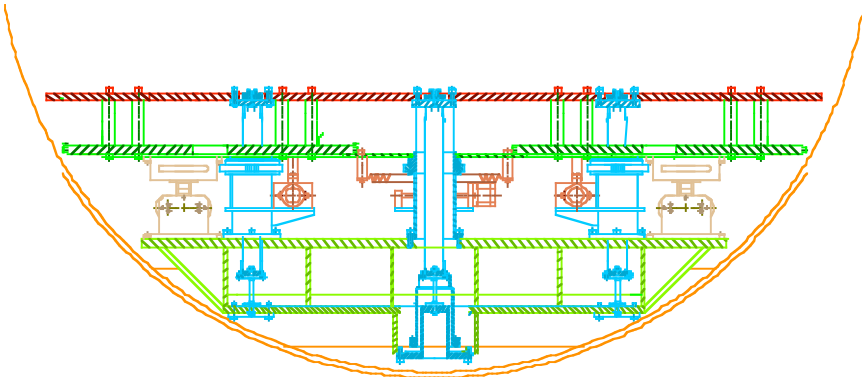


Transition from LIGO-I to Adv-LIGO

- The transition between

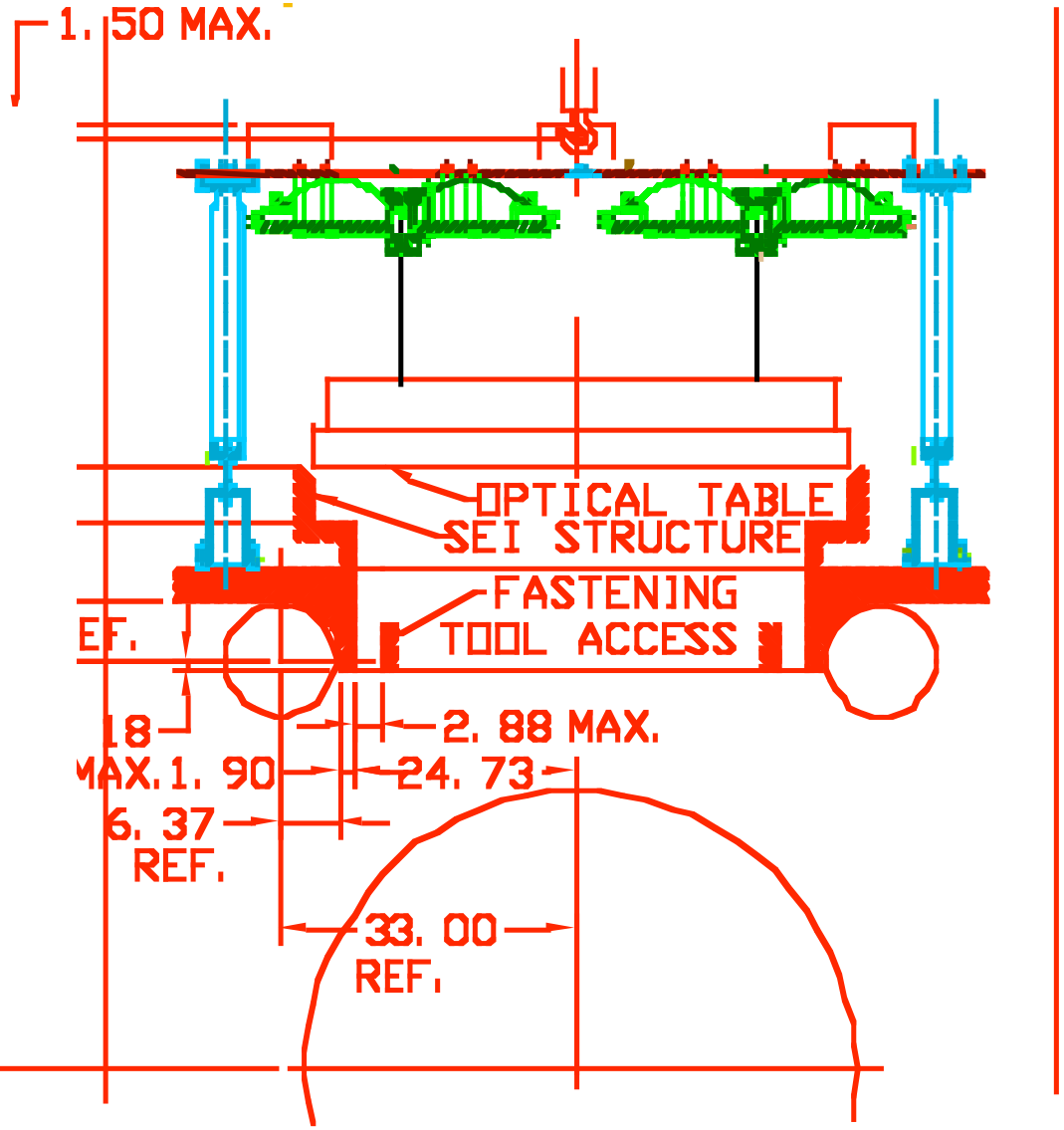
  LIGO and Advanced LIGO is obtained by simply eliminating a number of spacers





SAS compatibility with BSCs

- Move IP legs to larger diameter
- Hang optical bench below the spring box



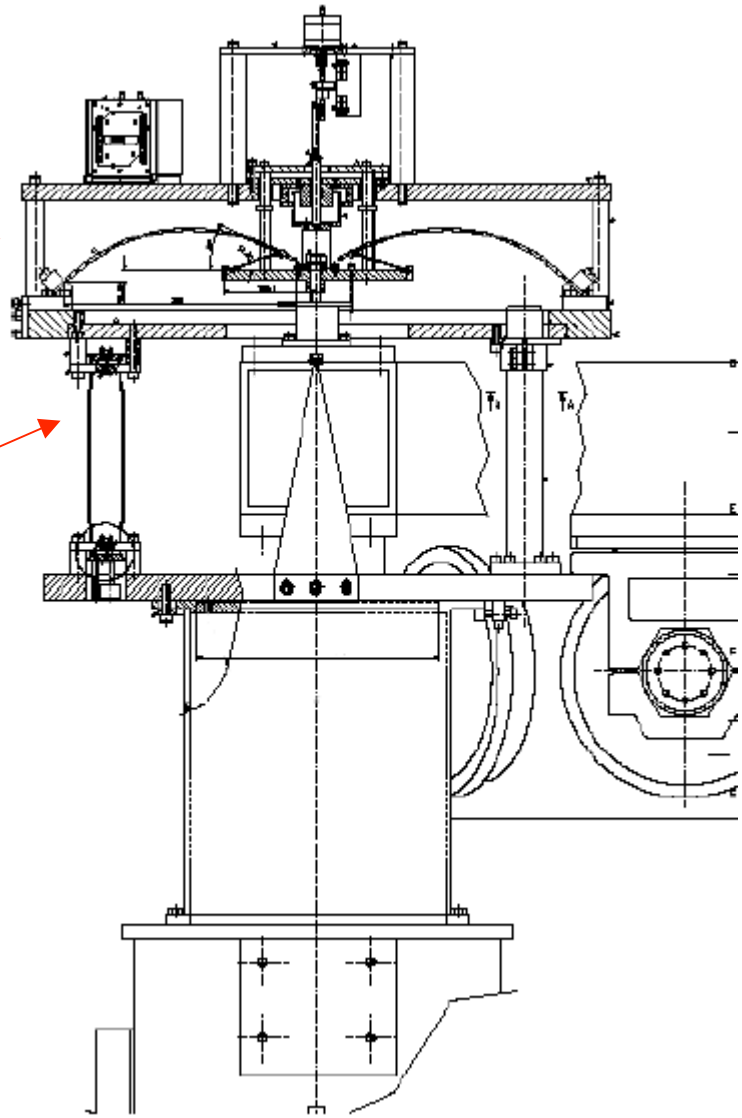
BSC SAS

- The SAS design fits in the BSC and satisfy its requirements
- An additional pendulum stage, needed to reach the (lower) level required by the quad suspensions, gives a redundant safety factor in horizontal isolation

Possible improvements: external pre-isolator

Vertical Attenuation

Horizontal Attenuation

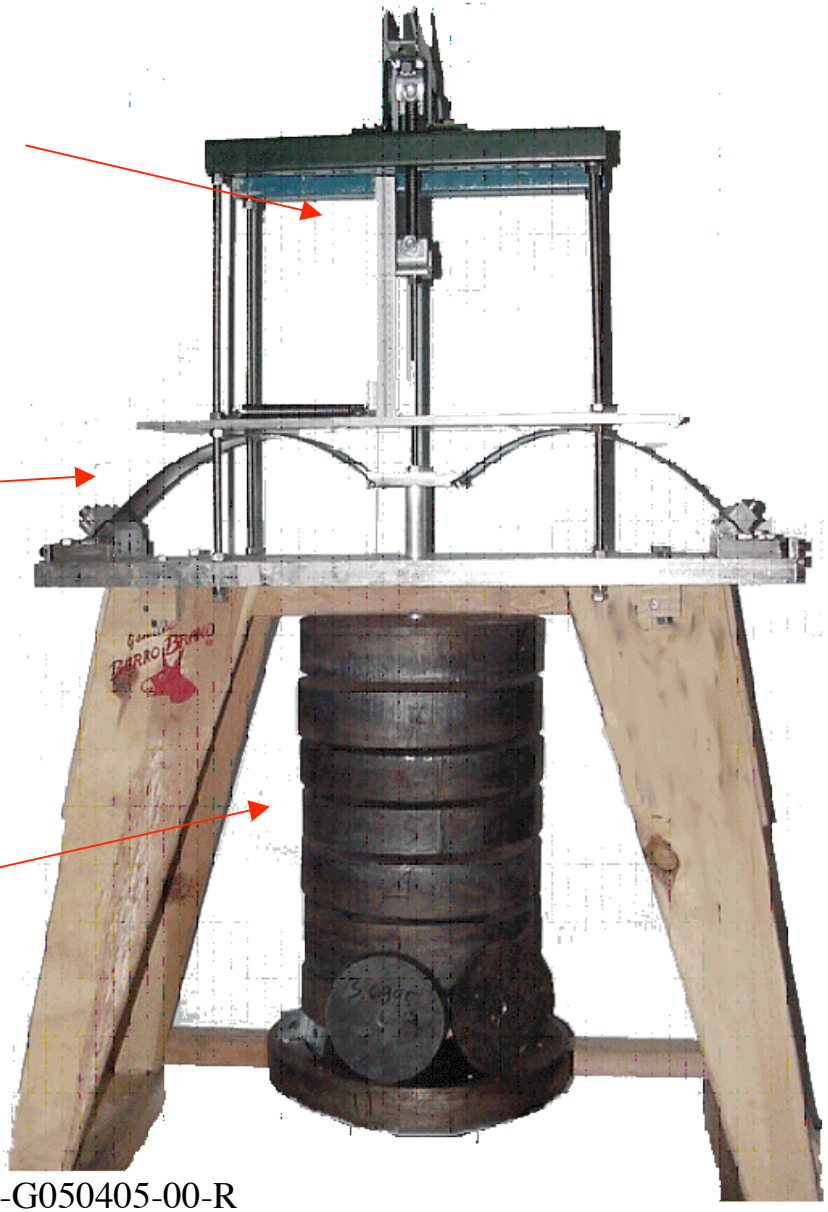


DFBS prototype

Bellow equivalent springs
(neutralized by GAS)

Cantilevers
GAS springs

350 Kg Payload



HAM SAS features

- The expected passive attenuation performance should exceed 60 dB above 1 Hz
  - (Vertical 40 dB above 1 Hz and 60dB above 5 Hz)
- The performance of HAM-SAS can be complemented with one stage of active attenuation, if necessary, thus providing a reserve of attenuation power

HAM SAS features

- SAS is a viable, simple and inexpensive in-vacuum seismic attenuation system for the LIGO OMC and all Adv-LIGO HAMs
- Can replace all three stages of stiff SEI
- fully compatible with the SUS system
- Scaling of the design is possible for BSC

Ham SAS features

- In case of attenuation shortfalls or additional requirements can implement a supplementary external pre-isolator

HAM SAS design status

- A complete HAM SAS design is ready for production LIGO D050100 to D050199
  http://www.ligo.caltech.edu/~desalvo/HAM-SAS.doc
- Cost estimations indicate a mechanical components cost of < 200K$ and production times of the order of three months
- Ready for immediate production
- Prototype for LASTI in 9 months
- Production of first units for OMC installation in sites after S5