LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO- T060002-00-E *LIGO* January 5th, 2006

SAS installation and tuning procedure

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Distribution of this document:
LIGO Science Collaboration

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SAS installation and tuning procedure

The SAS installation and tuning is a two-step process, first the SAS is factory or laboratory pre-tuned and cabled, then a final, fine-tuning is performed once the SAS is installed inside the vacuum chamber. Subsequent changes of the optical payload mass and/or positioning only require mass swapping between the optical and the ballast payload and a last fine-tuning step with parasitic tuning springs.

Factory pre-tuning.

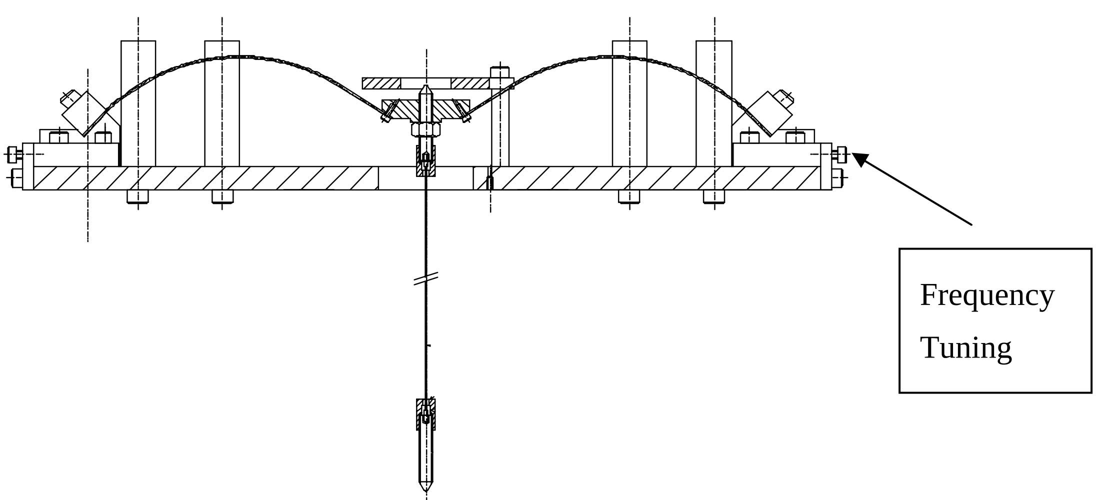
The factory pre-tuning is intended to tune the GAS filters to 200 mHz (± 50 mHz) of mechanical resonant frequency, the GAS filter counterweights to allow vertical attenuation above 60 dB and the IP table below 60 mHz.

GAS tuning

The GAS filter is assembled with the number and choice of blades necessary to meet its payload requirements (1/4 of the sum of the bench, the ballast and the optical payload weight).

The GAS filter frequency tuning is obtained by loading each single filter to its nominal payload and tuning its resonant frequency by means of the removable screws mounted on the periphery of the filter plate. The tuning procedure is also described in chapter 2 of LIGO-D050198-01-D.

The stiffness of the vertical parasitic tuning springs and cabling (acting in parallel to the GAS springs) Are also taken into account by mounting a parasitic tuning springs and suitable cabling (5 cables with the proper free length) in parallel to the GAS during this step.



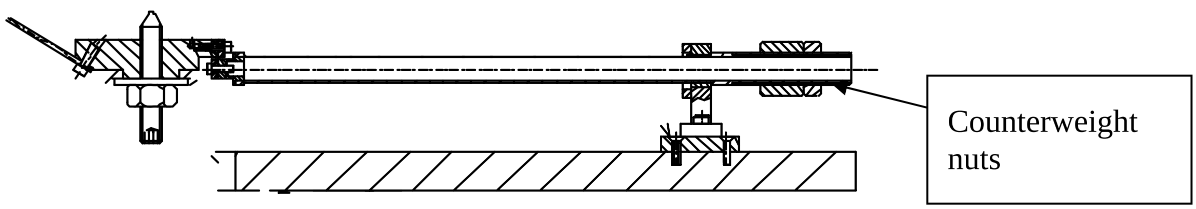
The resonant frequency tuning of a filter is a robust setting, much less sensitive to thermal and mechanical changes than the vertical working point. Requiring that the vertical working point does not creep within nanometers, which is achieved with soft baking of the GAS filters, as demonstrated in the HAM SAS configuration in [T050047], is a much more stringent requirement than requiring stability of the resonant frequency within less than a percent.

No measurable change of a filter resonant frequency was ever observed for anything less than violent damage to its structure and no further tuning is necessary after the factory pre-tuning and baking[1].

Once the filter mechanical resonant frequency is tuned, all that has to be guaranteed during installation is that the filter is loaded to its nominal mass (by means of appropriate ballast mass for gross tuning and parasitic tuning spring for fine tuning) and the filter performs to its resonant frequency.

Lowering the resonant frequency below 200 mHz is performed electronically by tuning the e.m. spring in the filter once the SAS is in operation.

The second mechanical tuning for a GAS filter is the tuning of the counterweight of the wand(s) compensating its Center Of Percussion. The tuning involves shifting the position of two tuning nuts over the length of the back stem of the wand.



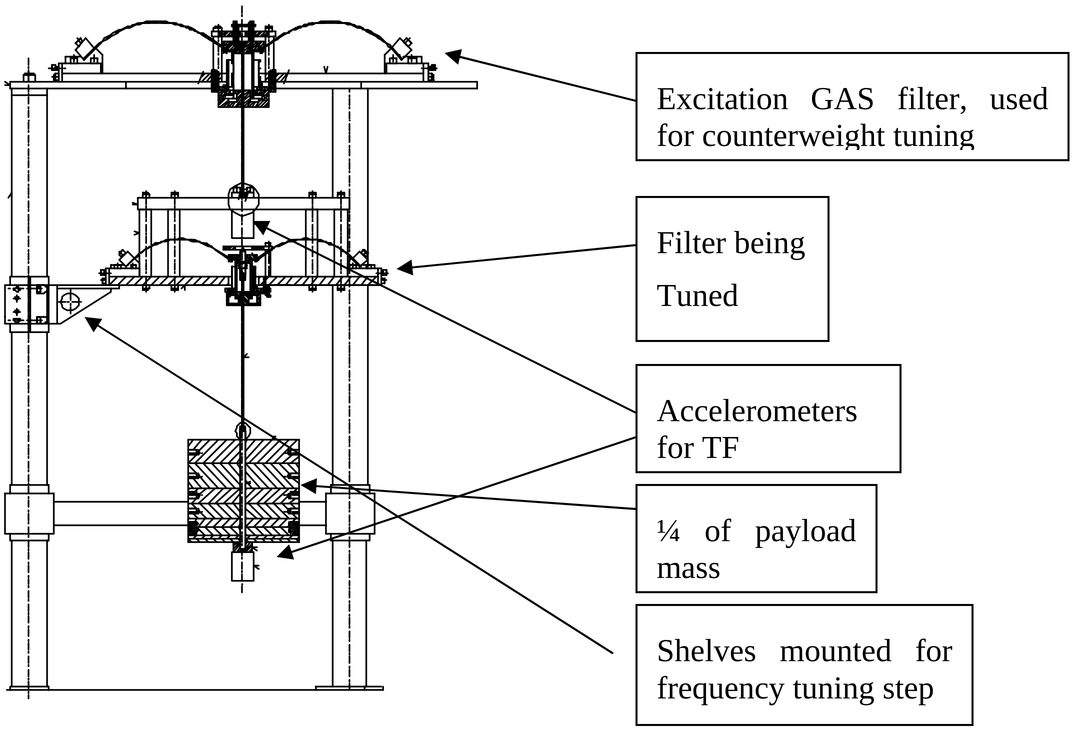
The amount of compensation required is only a function of the mass distribution in the blades and does not change with time.

The tuning is performed by oscillating in the vertical direction a loaded filter and measuring its transfer function for different positions of the counterweight nuts.

It is even possible that, with experience, the tuning nuts could be replaced with a pre-shaped, not-tunable, monolithic wand. This simplification would fix the number and size of blades employed, and is not foreseen for the LASTI prototype.

The tuning of the wand requires a tuning setup in which the voice coil actuator of an external GAS filter is used to vertically oscillate the GAS filter under tuning procedure.

[1] It has been observed (with poor quality blades) that changes of vertical working point of a GAS filter appear much earlier than any measurable change of frequency. The GAS filters are pre-aged (by oven ageing) for more than a billion year-equivalent, to guarantee creep of the filter working point of less than a nm/year. It is therefore never required to change the factory mechanical frequency tuning.



IP tuning

The IP table resonant frequency is uniquely determined by the payload imposed on it.

Its tuning is obtained independently from the GAS filter tuning by mounting a small amount of ballast mass on the spring box below the GAS filters.

The IP payload is determined by the overall elasticity, given by the flex joint diameter and the tuning spring stiffness.

Drastic changes of payload (beyond what is achievable by swapping mass between the optical payload and the bench ballast) require complete disassembly of the SAS and replacement of the flex joints. The intent is to keep the total payload mass constant for all HAM chambers (just as for initial LIGO). Note that after the first pre-tuning, the IP load tuning is automatically restored by each re-tuning of the GAS filters, whose vertical working point tune is more mass sensitive than the IP legs, with no need of altering the spring box ballast mass. In other words as long as the optical payload and the ballast are modified without changes of overall mass and load distribution between the four GAS filters (as planned), there is no need of GAS or IP re-tune.

Note. We previously foresaw an overall measurement of the SAS Transfer Function. This measurement would have required a complex testing setup (As.y Dr. D051149 to 151 and 156) and would have yielded performance in less than perfect conditions. It was later decided to forgo this test.

Installation in the HAM vacuum chamber

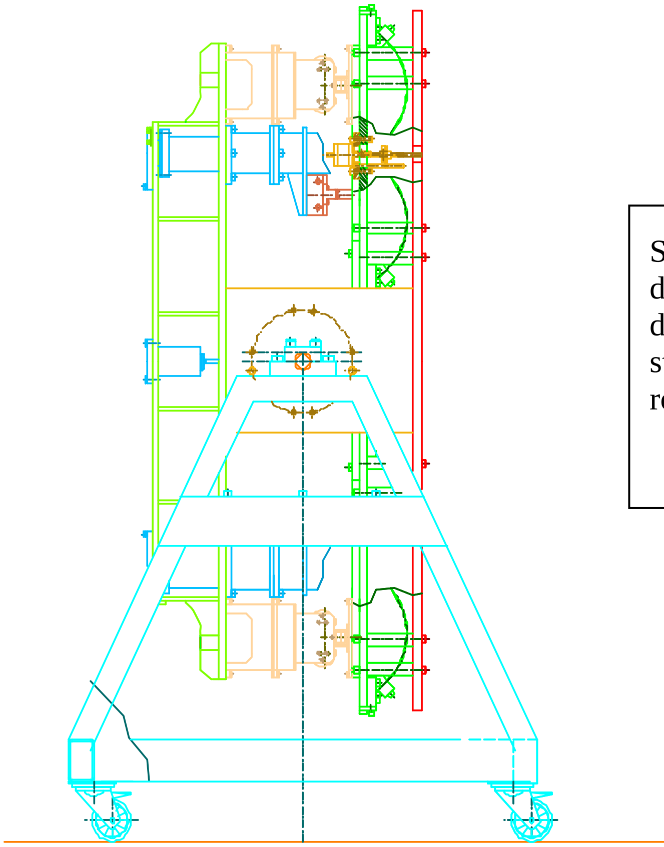
Unlike the BSC or the TAMA vacuum chambers, that require vertical installation, the HAM chambers require horizontal insertion. This requires substantially more sophisticated installation equipment, illustrated in assy. D051186 to D051194.

The SAS is installed in a HAM chamber as a single, factory pre-tuned, pre-cabled unit. All movement are frozen with suitable clamps, following a procedure developed for the TAMA 3 m and TAMA installation, where units comprising an entire pre-isolator (equivalent to the HAM SAS) and the attenuation and suspension chain (equivalent to the quadruple pendulum) were shipped from the assembly and pre-tuning location (Pasadena for the TAMA 3 m experiment, and the old 20 m interferometer hall for the TAMA installation) and installed within a single day.

View of a TAMA SAS unit pre-assembles, tuned and packaged in a NAO clean room, ready for transportation and installation in the main TAMA experimental hall

The HAM optical bench, with its optical payload, is installed in a second step.

The factory pre-tuned and immobilized SAS is partially unpacked and mounted on a cart that allows rotation of the SAS units to pass through normal doors and negotiate tight bends in the experimental hall. The cart brings the SAS unit directly in front of the HAM chamber.



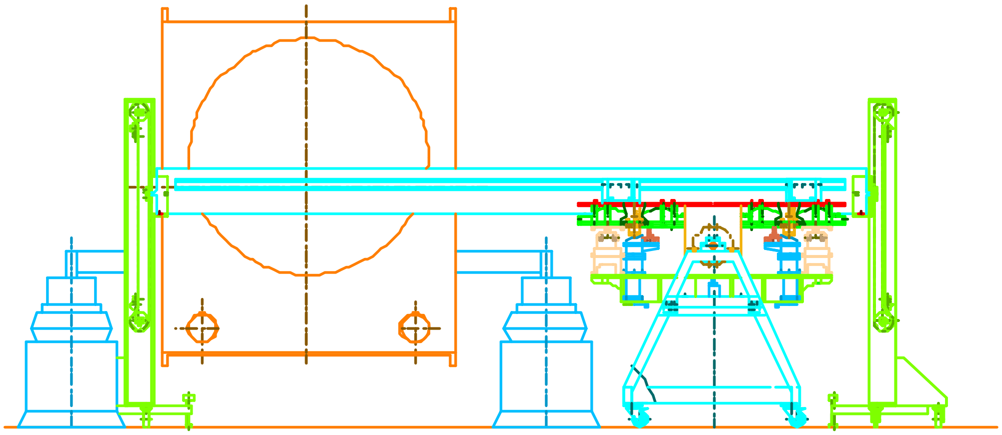
SAS unit on its cart, rotated 90 degrees for passage through lab doors. At this stage the unit would still bagged after the factory clean room assembly and baking.

When in front of the HAM chamber the SAS unit is rotated into its horizontal position.

A pair of special lifting carts is positioned straddling the HAM chamber. The two carts are linked by two rails that run across the HAM chamber. Each rail is equipped with two low friction carriages.

The rails are lowered 500 mm to allow the SAS unit to be bolted to the four carriages.

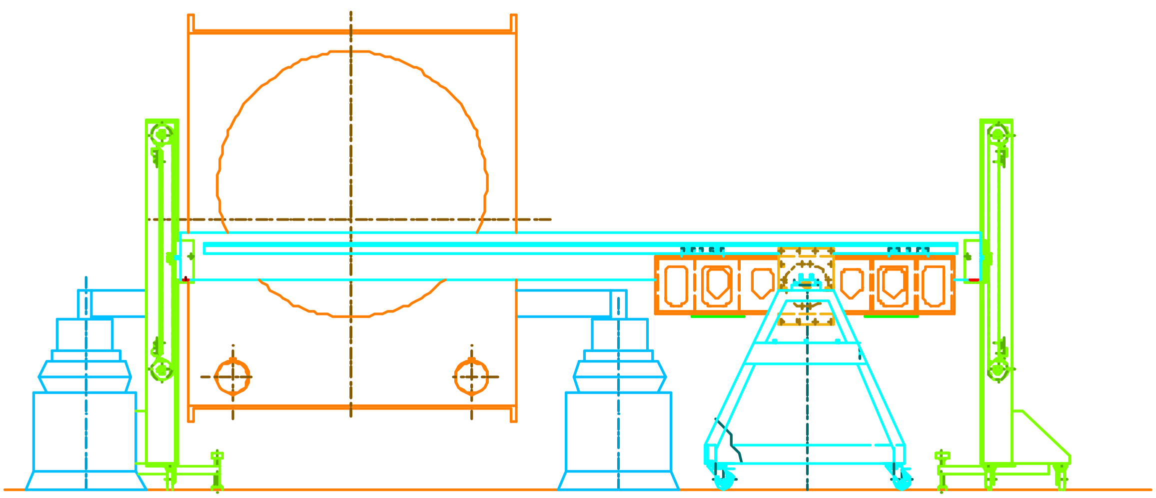
The rails are raised 500 mm lifting the SAS unit over the pier impediments.



The unit is pushed into the HAM chamber, lowered 450 mm to fit over and be bolted to the cross tubes.

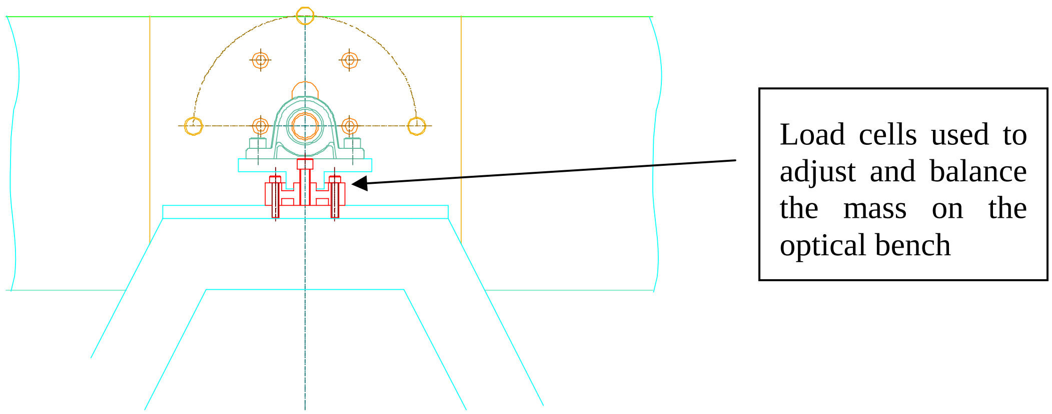
Cabling connection to the vacuum feed-through are made.

The operation is repeated for the optical bench except for the fact that the optical bench needs not be raised above its intended position for insertion.



Note that, although bench loading with its optical payload and ballast, as well as balancing, can be done inside the HAM chamber, this operation is much more easily performed externally, while the bench is still sitting on its cart.

To allow correct loading and balancing of the weight on the bench, the cart is equipped with load cells



After this the entire optical bench can slide in place horizontally and only minimal adjustments of ballasts will be necessary, to compensate optics re-positionings or last minute replacements. The optical bench sits on a kinematic mount and will not require bolting. Only hooking of the parasitic tuning springs and connection of electrical cablings will be necessary.

After the optical bench is sitting on the GAS springs, fine alignment and balancing is performed using small ballast masses and, finally the tunable parasitic springs.

All payload modifications can be performed in situ as long as they do not exceed the ballast allowances.

The above installation scheme has the additional convenience of allowing extraction of the optical bench at a moderate effort investment for major optics payload modifications.