Passive damping solutions for the BSC-ISI and Quadruple Pendulum structural modes

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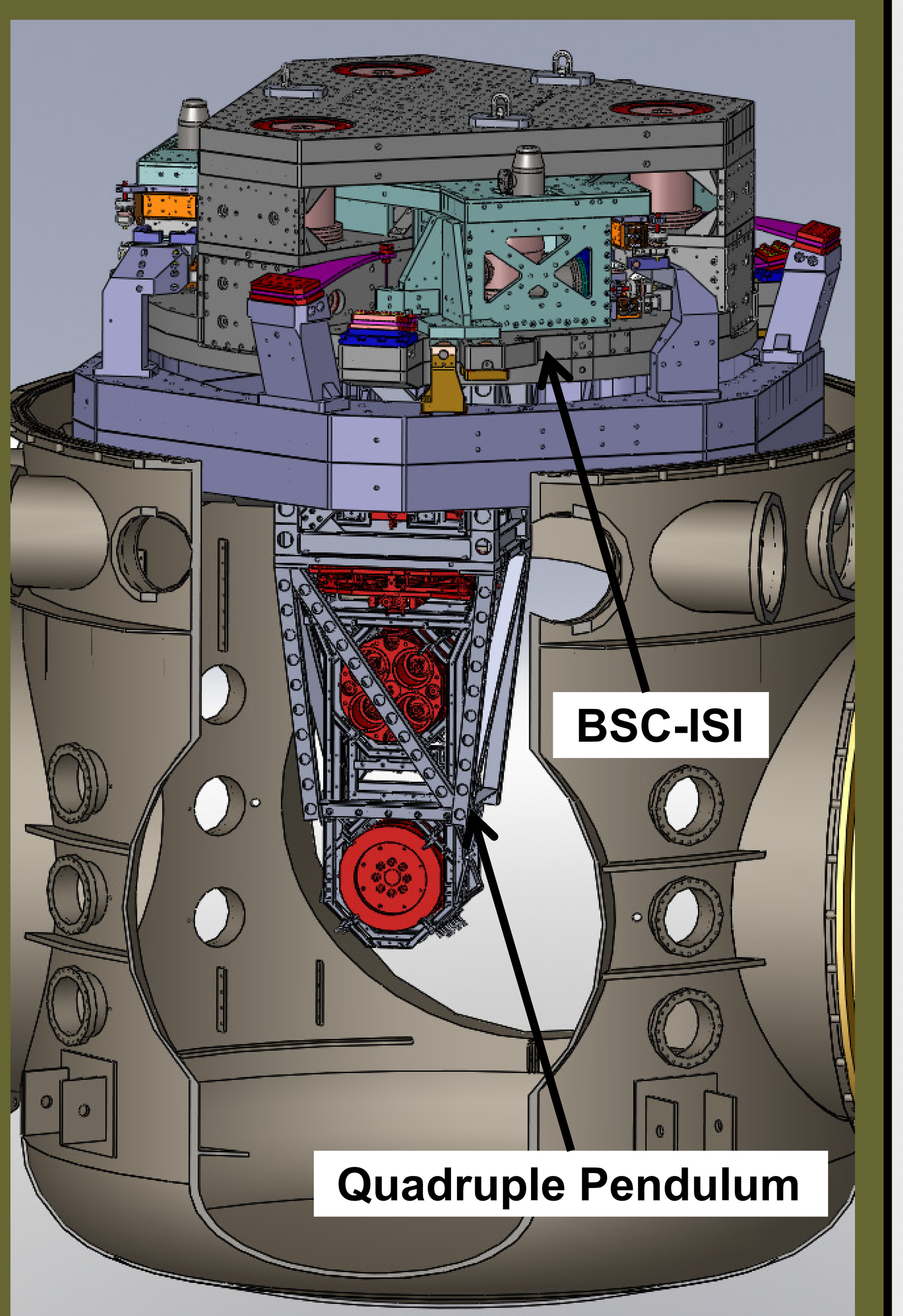
ABSTRACT

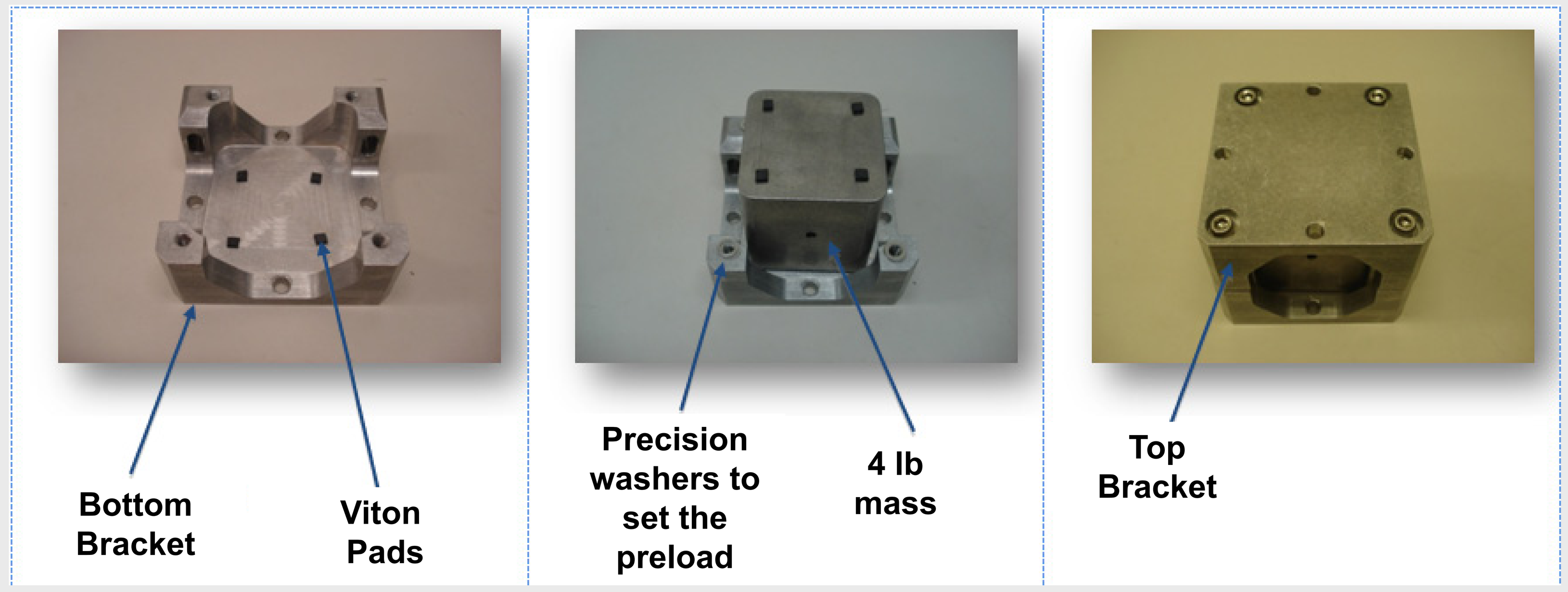
The commissioning of the prototype BSC-ISI has discovered a large number of structural resonances making the active control complicated. These modes are due to both the BSC-ISI structure and its payload, a quadruple pendulum structure. In order to passively damp these modes, two devices have been designed and tested:

- "vibration absorber" installed on the quadruple pendulum structure
- "keel mass dampers" installed on the top of stage 2

The combination of these two approaches has reduced the Qs of most of the low frequency resonances by as much as two order of magnitude. This has significantly simplified the control laws, making them much quicker to design and much more robust.



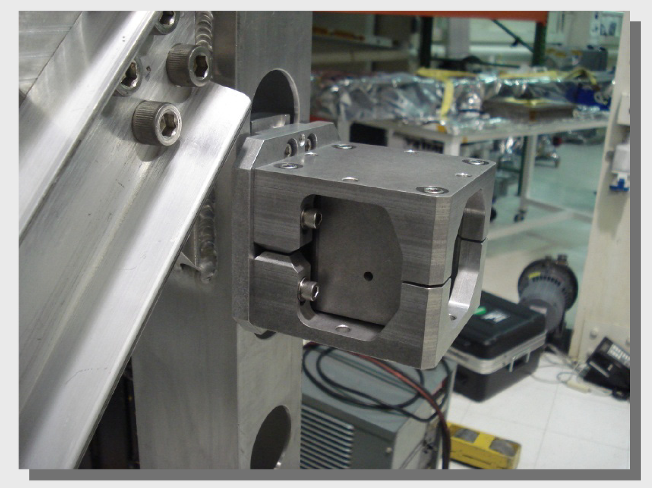
Vibration Absorber on the Quad



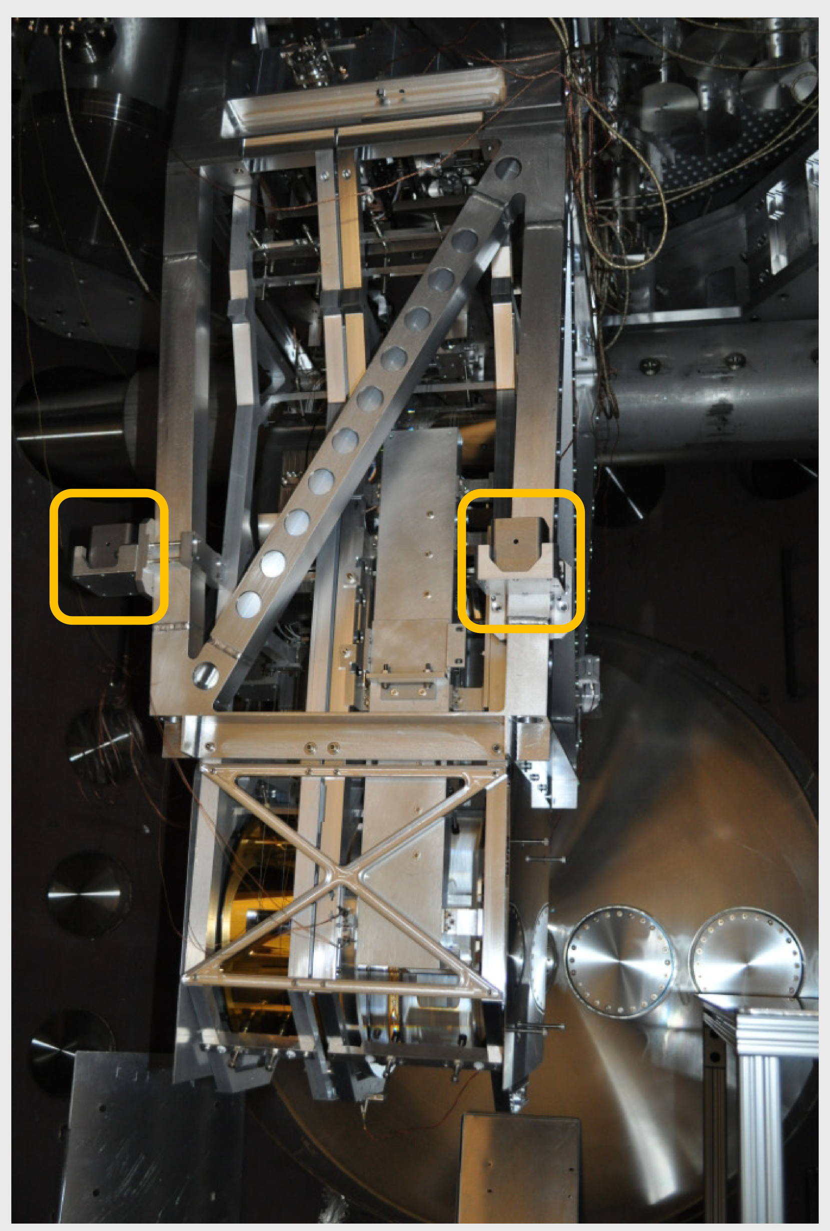
The vibration absorber is attached onto the quadruple pendulum structure in order to damp its resonances.

Contrary to a tuned mass damper, the frequency of the vibration absorber doesn't need to be tuned to a specific value: the damping action is broadband and efficient on all the low frequency modes of the structure.

The pictures at the top describe the device which consists of Viton pads constrained between a 4 lb stainless steel block and aluminum brackets. The pad geometry is simply chosen to set the spring mass resonance below the first frequency to be damped.

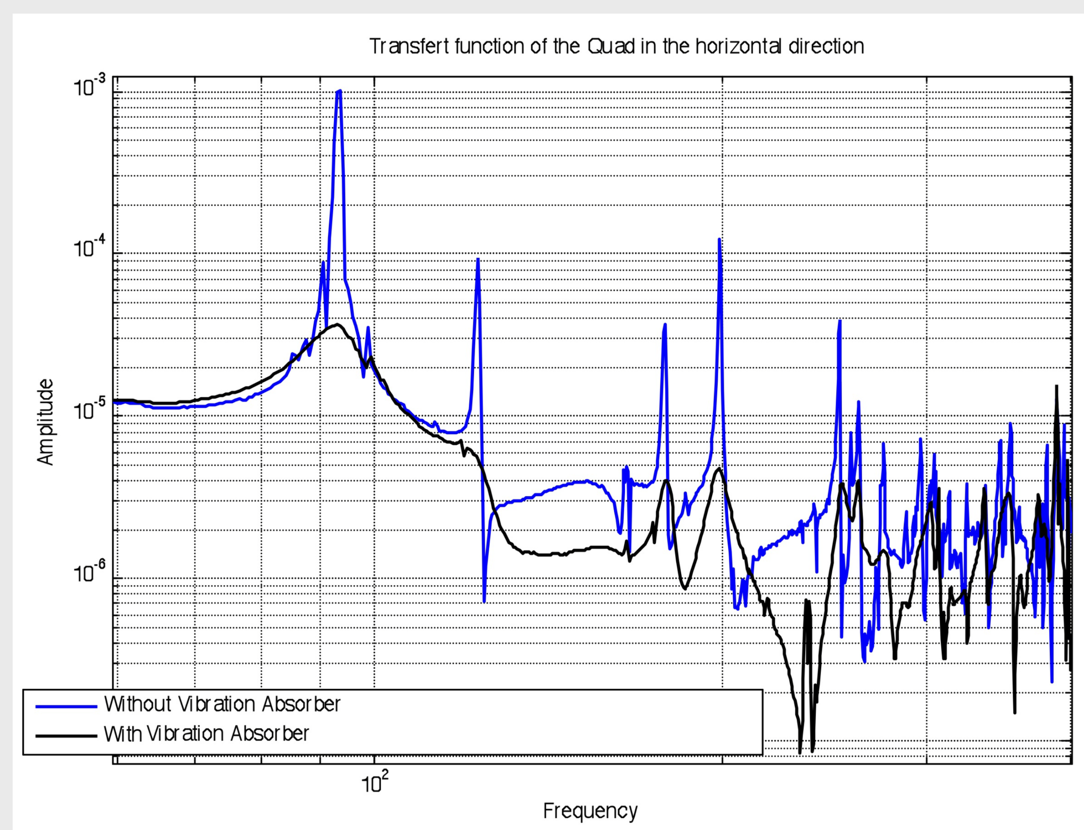


Vibration absorber on a mock up quadruple pendulum structure

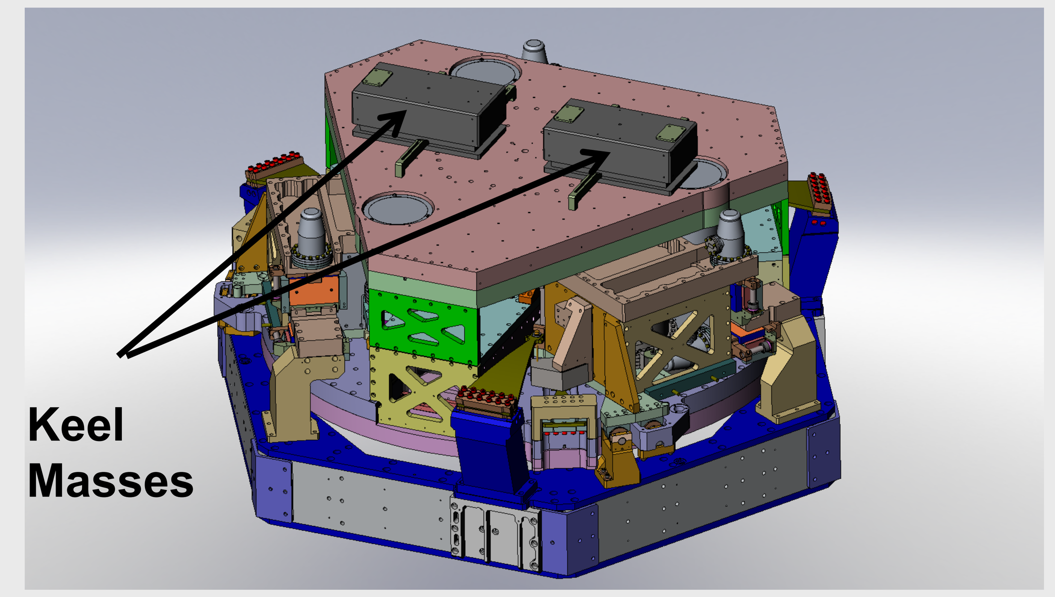


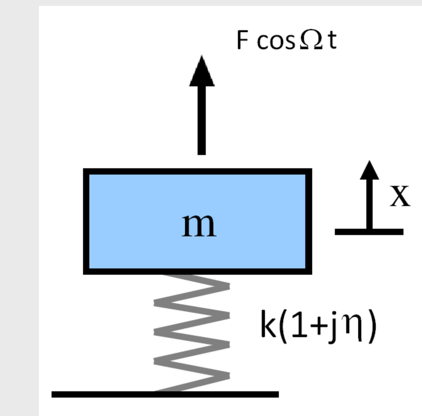
The picture below illustrates the damping that can be obtained using mass dampers on a Quad structure (preliminary testing using 20 lbs of mass dampers on a suspended mock up quad structure).

The picture on the left shows the vibration absorbers installed on the quadruple pendulum at LASTI.



Keel Mass Dampers on Stage 2



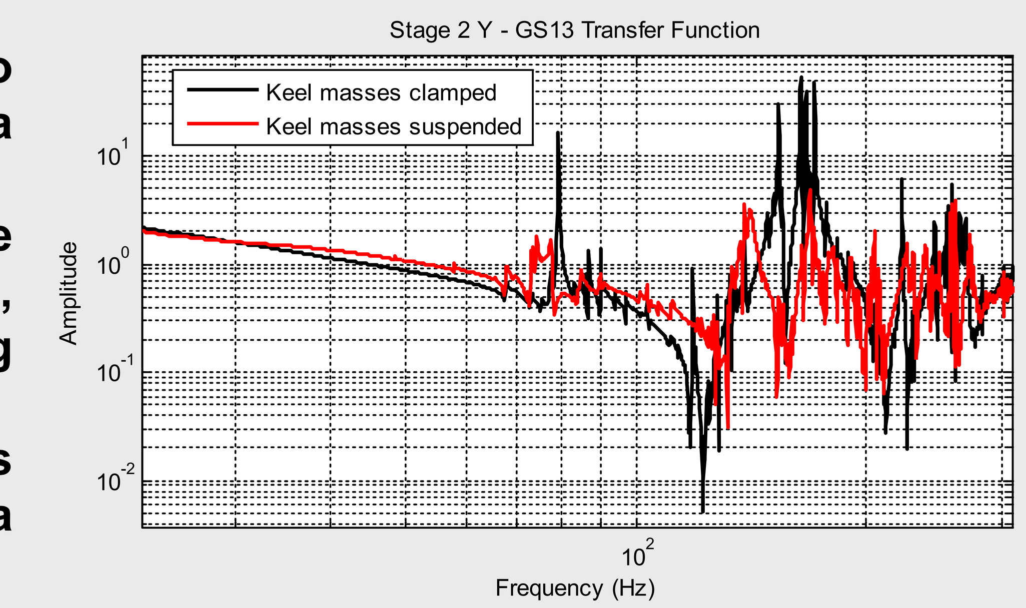


Model of the keel mass damper. The Viton pad provides both the spring and the damping.

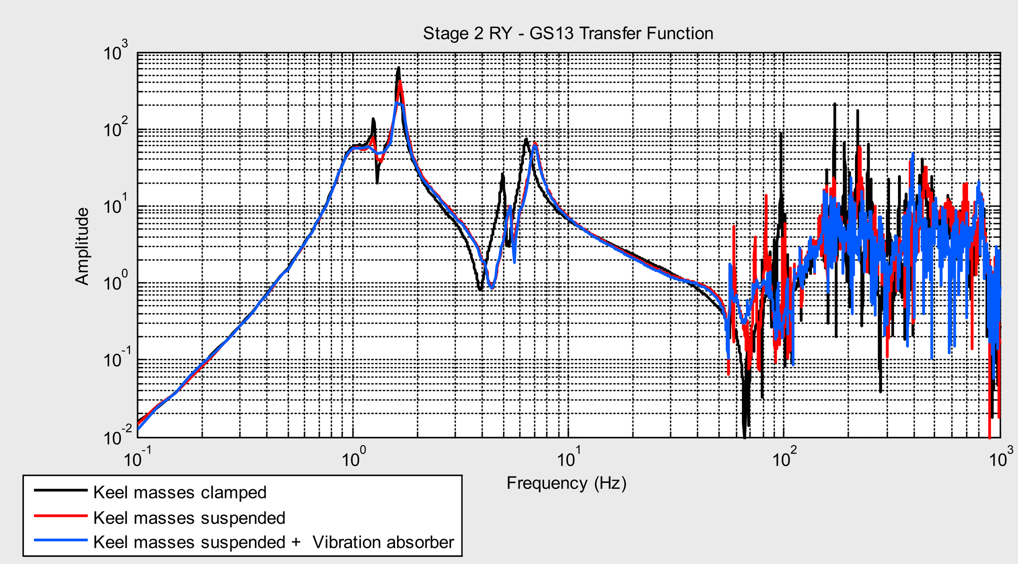
The BSC-ISI design includes two keel masses necessary to balance the system. These 400 lbs masses are used as a counterweight to the optical payloads.

The idea presented here is to use these keel masses to make spring mass dampers. The masses are mounted on Viton pads, whose dimensions have been tuned to set the mass-spring frequency around 60 Hz.

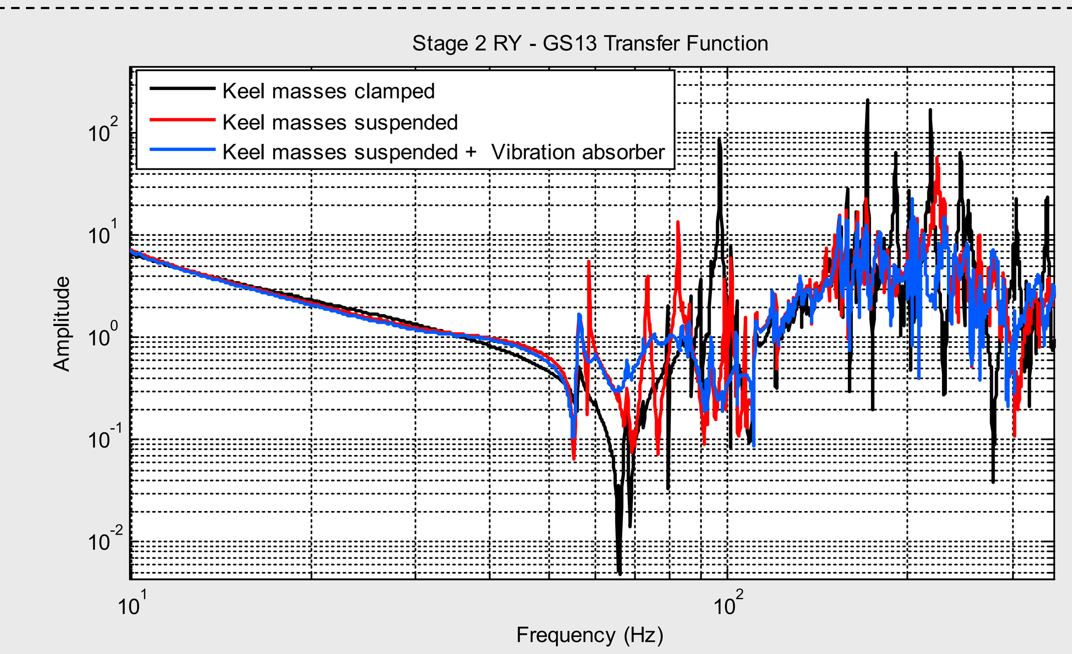
This approach damps many resonances under 200 Hz as shown in the graph on the right where the Qs are reduced by a factor of 10.



Overall Improvement & New Control Loops



zoom



The graphs above and on the top right corner show how the combination of "keel mass dampers" and "vibration absorbers" reduce the Qs of the main resonances by as much as two order of magnitudes.

The graph at the bottom right shows an example of a new controller for the BSC-ISI. The controller (green) is generic (20 Hz unity gain frequency, 35 degrees phase margin) and very robust as it does not contain any high frequency features: no notches, no plant compensation above the unity gain frequency, only a low pass roll off from 60 Hz to 250 Hz.