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Upgrading the Superattenuator: Towards an Active Seismic Pre-Isolator for Next-Generation Gravitational Wave Detectors

The Superattenuator has played a pivotal role in enabling the detection of gravitational wave signals in current generation interferometers down to an unprecedented 10 Hz, attenuating the ground motion at that frequency by many orders of magnitude. For next-generation gravitational wave detectors, aiming at improving the sensitivity by more than one order of magnitude and extending the detection band down to 2-3 Hz, further improvements are necessary to push the boundaries of detection capability.

The Superattenuator seismic platform was originally equipped with piezoelectric actuators in case of necessity to compensate significant effects of ground tilt at the top stage.
One key focus in the current R&D efforts is the upgrade of the seismic platform into a six-degrees-of-freedom active pre-isolator, exploiting the piezoelectric actuators for fine-tuned active control over a wider frequency range.
In the current Superattenuator design, the actuators are mounted in a mechanical support structure suitable for heavy loads. Recently, we revised the implementation, focusing on optimizing both mechanics and control strategies, also including the possibility of addressing the horizontal degrees of freedom.
Challenges include ensuring the actuator's reliable operation in both static and dynamic modes, long-term stability, and the ability to sustain significant mechanical loads over extended periods.
Current results obtained on a testbench-sized version of a Superattenuator installed in the INFN Pisa laboratory, allowing detailed measurement of transfer functions and noise analysis, as long as a comparison with simulations supporting accurate modeling, will be presented.

The lack of sensors of high enough sensitivity prevented so far active compensation for seismic motion in the very low-frequency regime.
In general, with improvements in passive and active filters, current state-of-the-art sensors will become excessively noisy.
This necessitates the development of new sensors based on principles distinct from those currently employed.
We will report on ongoing efforts on the developement of a new accelerometer, featuring a redesigned mechanical structure and optical interferometric readout, to address noise limitations in the low-frequency regime.

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