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Development of a high-resolution optical inertial sensor for sub-Hz seismic isolation

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Precision engineering tasks require active isolation systems that are efficient especially at low frequencies. The limitations of such control systems include the resolution of the sensor used and the magnetic coupling between the sensor and the actuator. In order to bypass these limitations, inertial sensors using Michelson interferometer are being developed. A first prototype has been built and tested. It has been shown that it has a sub-nanometer resolution over a large frequency range, extending from 0.1 Hz to 100 Hz. To further improve the resolution, a new optical design will be presented in this paper. The elements of the setup are chosen to lower the noise of the whole system. Actually, two main sources of noise can be reduced. The first one is due to the optical components, inducing a phase shift which is converted into a displacement error. The second is a consequence of the pendulum movement of the piece/spring holding the moving mass. It couples the vertical translation and the rotation. By choosing correctly the optical components, the first source can be diminished. The resolution reached is compared with that predicted by the optical model implemented on MATLAB. With the best optical resolution of the setup achieved, the interferometer had been integrated into a STS1 seismometer to reduce the pendulum movement. The optical sensor replaces the conventional capacitive sensor of the device without disturbing the mechanical parts. The resulting modified STS1 has a spectral resolution below 10^{-13} m/rtHz, while at the same time is insensitive to magnetic field.
The final objective of this research consists in introducing the inertial sensor into a single-axis isolation system equipped with a voice coil actuator. In feedback configuration, the setup will allow to reach an unprecedented high level of isolation, opening a new window in gravimetry and gravitational wave detection.

Summary

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