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First validation of a vertical cryogenic interferometric inertial sensor at 5.12K

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The sensitivity of existing ground-based observatories to gravitational-wave signals is limited at low frequencies, particularly around 10 Hz. This limitation arises from several noise sources, including coupling between the mirror motion and other degrees of freedom, seismic noise, and thermal noise. The Einstein Telescope (ET) is a third-generation gravitational-wave detector aiming to mitigate these noise sources, broadening its sensitivity curve down to 3 Hz and significantly increasing the observable volume of the universe and the number of heavier black-hole sources. Thermal noise contributions from the mirror suspension and the mirror coating can be efficiently reduced by cooling the payload to cryogenic temperatures, selecting a low-mechanical-loss material for the mirror, and increasing the mirror mass. Innovative low-frequency isolators must be developed to mitigate seismic noise. Technology validation for the ET must thus be conducted in an extremely low-vibration, cryogenic environment to simulate the target environment. This harsh environment calls for a highly sensitive cryogenic-compatible inertial sensor for vibration monitoring and reduction in the test facilities. To that end, cryogenic, vacuum-compatible, horizontal and vertical inertial sensors with a sensitivity of 10 fm/√Hz from 1 Hz at 20K are developed. This presentation collects the first validations conducted on the vertical version of these sensors. Its proper operation under cryogenic conditions was first assessed by testing critical sub-components and validating the sensor design robustness to thermal variations. It was then integrated into a large-scale cryostat at the Institute for Gravitational Research (IGR) at the University of Glasgow to monitor vibration levels in this future ET technology validation facility. The vertical cryogenic interferometric inertial sensor demonstrated perfect operation down to 5.12K. Its measurements were validated over the range of 0.2 to 100Hz using witness sensors placed near the cryostat, proving its reliability in this harsh environment.

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