Absolute laser frequency reference for next generation inter-satellite laser interferometry

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The Gravity Recovery and Climate Experiment (GRACE) missions rely on inter-satellite interferometry to measure changes in the Earth's local gravity over months and years. These measurements provide a critical tool for understanding large scale mass transport, particularly movement of water and ice.

The next generation of GRACE-like missions are expected to rely on laser interferometry as the primary science measurement, requiring a new technique to provide long term frequency stability over timescales of months and years.

We have previously demonstrated a simple phase modulation scheme that is able to measure changes in laser frequency over long timescales using measurements of the optical cavity's free spectral range. The proposed technique uses hardware that is predominantly already baselined on the mission, requiring minimal changes to existing flight qualified hardware, and enabling tracking of the stability of the cavity free spectral range against a GPS disciplined OCXO for absolute laser frequency knowledge.

The technique has demonstrated performance exceeding the expected mission requirements [1], as well as compatibility with existing flight hardware. We have also calibrated the technique to absolute frequency by comparing with an atomic reference and have validated an approach for on-ground calibration to allow the absolute frequency to be determined in orbit [2].

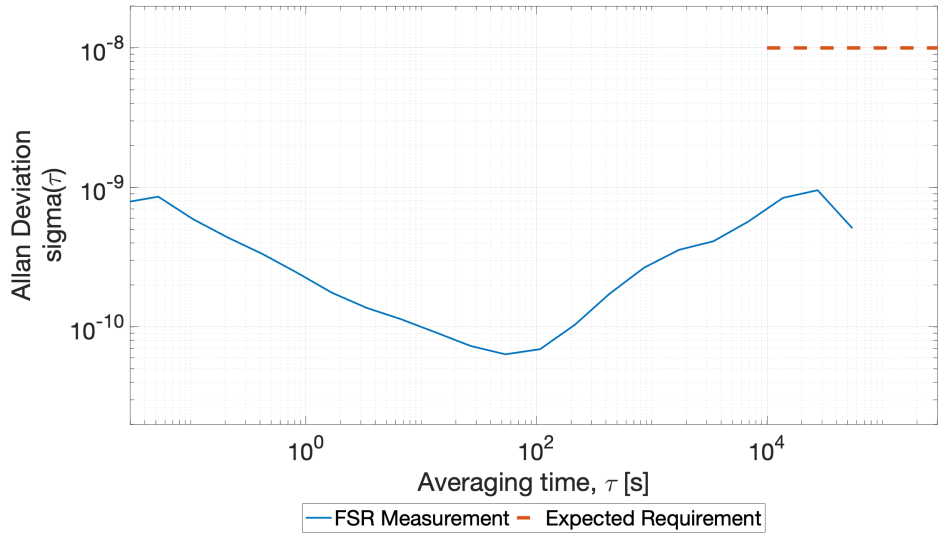

Fig.1. Allan deviation of the FSR measurement. Performance an order of magnitude below the expected requirement has been achieved.

References

[1] E. R. Rees, A. R. Wade, A. J. Sutton, R. E. Spero, D. A. Shaddock, and K. McKenzie, 'Absolute frequency readout derived from ULE cavity for next generation geodesy missions', *Opt. Express*, vol. 29, no. 16, pp. 26014–26027, Aug. 2021, doi: 10.1364/OE.434483.

[2] E. R. Rees, A. R. Wade, A. J. Sutton, and K. McKenzie, 'Absolute Frequency Readout of Cavity against Atomic Reference', *Remote Sens.*, vol. 14, no. 11, p. 2689, Jun. 2022, doi: 10.3390/rs14112689.