Model of Fiber-Optic Torsion Gravimeter Based on Tilted FBG for Continuous Gravity Field Monitoring

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SUMMARY

One of the key challenges in geodesy is the lack of a continuously operating, high-precision gravimetric infrastructure to support the International Height Reference System (IHRS). Relative gravimeters, while sensitive to ~0.1 μGal, are expensive, require manual operation, and are unsuitable for long-term autonomous monitoring. The paper presents a novel approach to gravity sensing using fiber-optic technology, specifically tilted fiber Bragg gratings (TFBGs), integrated into a differential torsion-lever gravimeter configuration.

The proposed model of sensing element replaces conventional displacement transducers with optical fibers that simultaneously serve as elastic torsion suspensions and strain-sensitive waveguides. Two standard SMF-28 fibers, each inscribed with five TFBG segments, are mounted symmetrically on opposite sides of a lever arm carrying a proof mass. When gravity changes, one fiber twists while the other untwists, enabling common-mode rejection of thermal and environmental noise while doubling the useful signal. Using an industrial interrogator with 1 pm wavelength resolution and a TFBG torsional sensitivity of 0.3 nm/(rad/m), the system can achieve a theoretical resolution of 20 μGal at a signal-to-noise ratio greater than 3.

A key advantage of the design is its use of torsional deformation of the elastic system—the dominant response mechanism in high-sensitivity gravimeters—rather than axial strain. This approach overcomes the limited sensitivity of standard fiber Bragg gratings to linear strain (~1.2 pm/με) and instead exploits the enhanced torsional sensitivity of tilted fiber Bragg gratings (TFBGs). The all-silica construction ensures low thermal drift, while the differential readout scheme enables effective compensation for temperature-induced disturbances.

Furthermore, the architecture is inherently scalable: multiple sensors can be multiplexed along a

single fiber, and interrogators can be linked via dedicated optical lines to form regional or even continental gravimetric networks. Modeling a 7,000 km chain (Moscow–Vladivostok) shows that with 70 such TFBG-gravimeters and 100 s signal averaging, accumulated error can be reduced to 0.02 mGal, enabling real-time monitoring of gravity changes with microgal-level precision over intercontinental distances.

This approach enables fully automated, remotely operated gravimetric networks compatible with existing telecom infrastructure, offering a cost-effective pathway toward a dynamic, fiber-optic-based IHRS.