Fiber Bragg Grating Calibration Method

Overview

Abstract In this paper we propose and demonstrate two alternative methods for the high-precision calibration of fiber Bragg grating (FBG) interrogators.

Key Takeaways

FBG parameter calibration involves mapping the Bragg wavelength shifts to physical quantities like temperature or strain using static or dynamic methods, optimized grating parameters, and nonlinear correction techniques.

Overview of FBG Calibration

Fiber Bragg Gratings (FBGs) are optical sensors where the Bragg wavelength shifts in response to strain or temperature changes. Calibration is essential to establish the relationship between the measured wavelength and the physical quantity, ensuring accurate sensing in applications such as structural health monitoring, aerospace, and medical devices. The calibration process typically involves measuring the Bragg wavelength under known conditions and creating a mapping function.

Static vs Dynamic CalibrationStatic Calibration: Involves measuring the FBG response at discrete, controlled conditions (e.g., fixed temperatures or applied strains) and fitting a polynomial or other model to the data. This method is widely used but may suffer from limited coverage and slower adaptation to changing conditions. Dynamic Calibration: Uses online learning algorithms, such as the Online Sequential Extreme Learning Machine (OS-ELM), to continuously update the calibration model as new measurements are obtained.

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This approach improves long-term stability, predictive accuracy, and generalization, especially when environmental conditions vary. Nonlinear Calibration ConsiderationsFBG sensors often exhibit nonlinear responses, particularly over wide temperature ranges. Nonlinear calibration involves: Measuring the Bragg wavelength at key reference points (e.g., 0°C using ice water) and interpolating for intermediate values.

Using polynomial fitting (e.g., fifth-order) or neural networks to model the nonlinear relationship between wavelength and temperature. Accounting for thermal expansion and thermo-optic effects, which influence the effective refractive index and grating period.

Optimal Grating Parameters

The spectral characteristics of FBGs, such as reflectivity, bandwidth, and sidelobe intensity, depend on grating length, index modulation, and apodization profile: Optimal grating length: ~5 mmIndex modulation: ~0. 0008Apodization profiles: sine, Gaussian, or raised sine for maximum reflectivity and minimal sidelobes These parameters ensure high sensitivity and accuracy in sensing applications.

Practical Calibration Steps

Prepare the FBG sensor: Ensure it is free from strain if calibrating for temperature, or fixed in a controlled environment for strain calibration. Measure reference wavelengths: Record Bragg wavelengths at known temperatures or applied strains. Fit calibration model: Use polynomial, neural network, or dynamic learning methods to map wavelength to the physical quantity.

Validate and adjust: Test the sensor under intermediate conditions to verify accuracy and adjust the model if necessary. Deploy with monitoring: For long-term applications, consider dynamic calibration to continuously correct for drift or environmental changes.

Conclusion

Effective FB

G parameter calibration combines accurate measurement, nonlinear modeling, and optimized grating design. Dynamic calibration methods enhance real-time performance and long-term reliability, while careful selection of grating parameters ensures high sensitivity and minimal spectral artifacts. This approach is critical for precise temperature, strain, or structural monitoring in demanding applications.

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Calibration Methods for Bragg Grating Interrogators

bration of fiber Bragg grating (FBG) interrogators. The first method is based on the direct comparison between the wavelength measurements of the interrogator under test and a calibrated wavemeter,

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The principle for calibration and strain sensing were discussed in detail. Lastly, different factors affecting the strain calibration process, such as temperature, were investigated. The results demonstrated the

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