

Fiber Optic Sensor for Measuring Elastic Modulus



Overview

Force-sensitive optical fiber fabric based on hollow elastic tube and. To address the challenge of achieving a wide force measurement range and high sens.

Key Takeaways

Fiber optic sensors, including FBG and LPG types, can accurately measure the elastic modulus of materials by detecting strain-induced changes in light transmission or resonance frequency. Types of Fiber Optic Sensors

Fiber Bragg Gratings (FBG) and Long-Period Gratings (LPG) are the most commonly used fiber optic sensors for elastic modulus measurements. FBGs have short periodicities on the order of the optical wavelength, while LPGs have longer periodicities spanning several hundred wavelengths. Both types create periodic perturbations in the fiber's refractive index, which modulate light transmission in response to mechanical strain. Reflective fiber optic sensors and polymer optical fibers (POF) are also used for dynamic measurements, particularly in vibration-based testing. These sensors can detect displacement, amplitude, and resonance frequency changes in materials under stress.

Measurement Principles

- **Strain-Induced Wavelength Shift:** In FBG and LPG sensors, mechanical strain alters the grating period, causing a shift in the resonance wavelength or attenuation dips in the transmitted light spectrum. This shift is proportional to the applied stress, allowing calculation of the material's elastic modulus.

- **Vibration-Based Dynamic Modulus:** By embedding an FBG sensor in a fiber and performing free vibration tests, the natural frequency of the fiber can be measured. Using the relationship between natural frequency and stiffness, the dynamic Young's modulus of the material or the fiber itself can be estimated without additional tensile testing equipment .
- **Reflective Sensing for Resonance:** Reflective fiber optic sensors can monitor the amplitude of vibrations on a material's surface. When the material reaches resonance under an applied excitation, the sensor detects maximum vibration amplitude, which can be used to calculate the dynamic elastic modulus .

Experimental Setup

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LPG Sensors: A CO₂ laser or UV laser is used to etch the grating onto a single-mode fiber. The transmittance spectrum is monitored while applying strain or bending to the fiber. The resonance wavelength shift is recorded and correlated with the applied stress .

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FBG Sensors: The fiber is embedded or attached to the test material. A light source and spectrometer measure the reflected Bragg wavelength. Free vibration or tensile tests provide data to calculate the elastic modulus .

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Reflective Fiber Sensors: A pair of optical fibers or a laser beam is used to detect scattered or reflected light from the vibrating surface. The amplitude and frequency of vibrations are analyzed to determine the dynamic modulus .

Advantages

- High sensitivity to strain and curvature.
- Non-contact measurement possible with reflective sensors.
- Can measure both static and dynamic elastic properties.
- Compact and suitable for harsh environments.

Applications

- Determining Young's modulus of metals, polymers, and composites.
- Monitoring dynamic mechanical properties during vibration or resonance tests.
- Structural health monitoring in civil, aerospace, and mechanical engineering.
- Integration with machine learning for advanced material characterization . Fiber optic sensors provide a versatile and precise method for measuring elastic modulus, combining optical sensitivity with mechanical analysis, and are increasingly used in both laboratory and industrial applications.

Article Content

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Optical Fiber Composite Young's Modulus: Theoretical Approach,

Abstract Acrylic coated high purity silica glass fibers (optical fibers) are widely used as a transmission medium in fiber optics

A fiber optic conjugate stress sensor for instantaneous

In this work, a surface-mounted fiber optic conjugate stress sensor (FOCSS) is developed,

A fiber optic conjugate stress sensor for instantaneous tangent modulus ...

In this study, the FOCSS data is used in conjunction with the lumped-element spring model to measure the elastic

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This paper conducts a systematic analysis of the sensing mechanisms in fiber-optic

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Young's modulus, as an important parameter in material mechanics, plays an important role in engineering design and teaching

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The measured Young's modulus distribution along the optical fiber axis could be used to analyze the damage degree

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In this work we determine the elastic constant, the Young modulus, and the strain limit of commercial optical fibers.

Portable polarimetric fiber stress sensor system for visco-elastic and ...

In the present work, we have solved these challenges by creating an all-optical fiber sensor system. Specifically, we

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We propose a novel experimental method, based on a fiber Bragg grating (FBG) sensor, to measure the elastic

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Fiber-based polarimetric stress sensor for measuring the Young's ...

Polarimetric optical fiber-based stress and pressure sensors have proven to be a robust tool for measuring and detecting changes in

Modeling of Distributed Sensing of Elastic Waves by Fiber-Optic

This paper deals with the transduction of strain accompanying elastic waves in solids by firmly attached optical fibers.

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An accurate determination of the physical properties of optical fibers is required to estimate the above stresses. Optical fiber is a

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Mechanical Properties of Optical Fibers

The FBG concept as sensor relies on the mechanical deformation of the optical fiber to measure static or dynamic parameters like

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