

Article Overview

Fiber optic sensors detect physical changes by modulating light properties, with detection frequency modes ranging from static measurements to high-frequency signals up to GHz levels depending on sensor design.

Detection Principles

Fiber optic sensors operate by converting environmental changes--such as strain, temperature, pressure, or electromagnetic fields--into measurable changes in light properties, including intensity, phase, polarization, wavelength, or transit time within the fiber . The detection frequency mode refers to the range of signal frequencies the sensor can accurately measure.

- o Intrinsic sensors detect changes within the fiber itself, often using interferometric techniques like Mach-Zehnder, Michelson, Fabry-Perot, or Sagnac interferometers. These sensors measure phase shifts induced by external perturbations, which can be converted into intensity changes for detection .
- o Extrinsic sensors use the fiber to transmit light from an external sensing element, allowing measurements in inaccessible or high-voltage environments .

Frequency Response

The frequency range of fiber optic sensors depends on the sensing mechanism:

- o Low-frequency or static measurements: Fiber Bragg Grating (FBG) sensors are commonly used for strain, temperature, and pressure monitoring. They detect changes in the reflected wavelength, with response times suitable for quasi-static or slowly varying signals .
- o High-frequency detection: Certain fiber designs exploit nonlinear effects, Faraday, or Kerr effects to detect electromagnetic fields in the 5 MHz-1 GHz range . Interferometric sensors can also detect vibrations and dynamic strain at high frequencies, limited by the optical path length and signal processing bandwidth .

Modulation and Detection Techniques

- o Phase modulation: Environmental changes induce a phase shift in the light traveling through the fiber. Interferometers compare the phase of a sensing fiber with a reference fiber to detect high-frequency signals .
- o Wavelength modulation: FBG sensors shift the Bragg wavelength in response to strain or temperature. The reflected wavelength is measured using spectrometers or wavelength demodulators, suitable for both static and dynamic detection .
- o Intensity modulation: Simplest method, where light intensity changes due to bending, absorption, or evanescent coupling are detected. This method is generally limited to lower frequencies due to detector

response .

Practical Considerations

- o Trade-off between range and bandwidth: Longer fiber lengths reduce the maximum detectable frequency due to time-of-flight limitations .
- o Signal processing: High-frequency detection often requires fast photodetectors and interferometric signal processing to resolve rapid phase or intensity changes.
- o Application-specific design: Hydrophones, vibration sensors, and electromagnetic field detectors are optimized for their respective frequency ranges, from Hz to GHz . In summary, the detection frequency mode of fiber optic sensors is determined by the sensor type, modulation method, and optical path design. FBGs excel in static or low-frequency measurements, while interferometric and nonlinear fiber sensors enable high-frequency detection up to the GHz range, making fiber optic sensors versatile for both slow and fast-changing physical phenomena.

Most recently in 2020, Pan et al. used a microbubble cavity combined with a digital optical frequency comb for

Standard single-mode telecommunication optical fiber is still one of the most popular in distributed acoustic sensing.

The fiber optic sensor working principle is that transducer changes some optical fiber system parameters like

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

Explore fiber optic sensors: their working principles, types (intrinsic, extrinsic, hybrid), and diverse

Hollow-core optical fibers hold good potential to create an ideal transmission environment akin to free space,

A simple frequency-unwrapping algorithm is proposed to extend the dynamic measurement range, and the continuous

To overcome these challenges, optical ultrasound sensors have emerged as a promising alternative, offering both high

We propose an all-optical miniaturized multigas simultaneous detection photoacoustic (PA) sensor, which is primarily

Fiber Optic Sensor Detection Frequency Mode

What is Distributed Acoustic Sensing (DAS)? Distributed Acoustic Sensing (DAS) is a technology that turns a fiber

communication system via using fiber optics there was a great demand to measure and sense the rate of data transmission, change

Here, the authors report mode-phase-difference photothermal spectroscopy with a dual-mode anti-resonant hollow

Abstract This review summarizes recent progress and emerging trends in multiparameter optical fiber sensing,

As shown by Jena et al., (2024) the team created an optical fiber seismic sensor for early sinkhole detection, sensing

While Brillouin scattering is an excellent strain sensor technology, the response time is about 1 second; and therefore, is not suitable

Experimental results show that the sensing system can realize highly sensitive detection of acoustic signals with the

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