Temperature Measurement with Multimode Fiber

Article Overview

Multimode fibers (MMFs) can serve as high-precision, non-contact temperature sensors using speckle patterns, multimode interference, or distributed sensing techniques.

Principles of MMF Temperature Sensing

Multimode fibers can detect temperature changes because the speckle pattern or interference of light propagating through the fiber is highly sensitive to environmental variations, including temperature. As light travels through the MMF, temperature fluctuations alter the refractive index and physical length of the fiber, causing measurable changes in the output light pattern or spectral characteristics . This allows the fiber itself to act as a distributed temperature sensor.

Techniques and Methods

o Deep Learning-Based Speckle Sensing By inputting the speckle pattern generated in an MMF into a Convolutional Neural Network (CNN), both the temperature and the location of heating points along the fiber can be predicted with high accuracy. Experiments have shown temperature prediction within +-1 ?C and location accuracy below 1 cm, making this method suitable for hazardous or hard-to-access environments .

o Multimode Interference (MMI) Sensing MMF sections can be used in single-mode-multimode-single-mode (SMS) structures, where the spectral dip shifts linearly with temperature. Sensitivity depends on core diameter, numerical aperture (NA), and fiber length. Larger core diameters increase temperature sensitivity, while longer fiber sections reduce it. This approach can also be designed to be strain-insensitive, improving measurement stability .

o Temperature Principal and Anti-Principal Modes Special light states in MMFs can be engineered to either enhance or reduce sensitivity to temperature fluctuations. Anti-principal modes amplify temperature-induced changes, improving sensor resolution, while principal modes provide robustness against environmental disturbances .

o Distributed Temperature Sensing (DTS) with MMFs MMFs with 50 um or 62.5 um cores and graded-index profiles are commonly used in DTS systems. Graded-index fibers reduce modal dispersion, improving signal-to-noise ratio and measurement precision over long distances. DTS systems provide continuous, real-time temperature monitoring along the entire fiber length, unlike point-based sensors .

Fiber Considerations

o Core and Cladding: The core transmits light, while the cladding confines it via total internal reflection.

o Coating: Polyimide or metal coatings are used for high-temperature or harsh environments, while polyacrylate is suitable for standard conditions .

o Core Diameter: Larger cores (e.g., 400-600 um) increase sensitivity but may reduce spatial resolution .

o Fiber Type: Step-index or graded-index MMFs are chosen based on the application, with graded-index preferred for DTS due to reduced modal dispersion .

Applications

MMF-based temperature sensing is widely applied in:

o Industrial and hazardous environments
o Fire detection and safety monitoring
o Environmental and structural monitoring
o Healthcare and fluid dynamics studies These methods offer non-contact, high-precision, and distributed temperature measurement, often outperforming traditional fiber-optic sensors in terms of installation simplicity, cost, and robustness . In summary, multimode fibers provide versatile and accurate temperature sensing capabilities, leveraging speckle patterns, multimode interference, and distributed sensing, with advanced techniques like deep learning further enhancing precision and spatial resolution.

In this paper, a novel inline optical fiber sensor for curvature and temperature measurement simultaneously has been

The results validate the feasibility of using OFDR for highprecision environmental sensing in multimode fibers, offering a new

In this review, we provide an overview of the latest developments in MMF sensors, ranging from conventional methods

Figure 1: Schematic diagram of the experimental setup for temperature and strain measurement; BLS, broadband light source; SMF,

A simple fiber sensor for dual parameters measurement of curvature and temperature is proposed and demonstrated,

In this work, a novel highly sensitive optical fiber temperature sensor utilizing a Mach-Zehnder modal interferometer

Abstract A multimode interference (MMI) sensor based on an SGNS structure (single mode fiber-graded index

A strain-insensitive high-sensitivity temperature sensor based on multimode interference in a specialty fiber

with a

A strain-insensitive temperature sensor based on multimode interference using standard multimode fibers (MMFs) is

The applications of these fibers provide possibilities to study specifically shaped core multimode fibers. In this

<p>This work introduces special states for light in multimode fibers featuring strongly enhanced or reduced correlations between

This paper compares the performance of single-mode and multimode fiber Bragg grating sensors for temperature

A fiber optics structure for temperature measurement is presented and demonstrated. This structure is composed of

Among all the reported applications, optical waveguides have been widely exploited to

Abstract A new fiber-optic sensor was demonstrated for temperature measurement using multimode interference effect

In this paper, a fiber laser sensing system based on neural network algorithm to measure temperature using beat

Web: https://www.kremgroup.co.za