

Design of a Multimode Fiber Optic Temperature Measurement and Monitoring System



Overview

Deep Learning-Based Multimode Fiber Distributed We designed an MMF-based temperature-sensing configuration and developed a dual-output Convolutional Neural.

Key Takeaways

A multimode fiber optic temperature measurement system can achieve high-precision, strain-insensitive sensing using MMF-based configurations combined with deep learning for real-time temperature monitoring and early warning.

Multimode Fiber Sensor Principles

Multimode fibers (MMFs) can serve as temperature sensors because temperature changes alter the speckle pattern or interference pattern of light propagating through the fiber. In MMF-based systems, a laser beam generates a speckle pattern that is highly sensitive to local temperature variations, allowing the fiber itself to act as a distributed sensing element. Multimode interference (MMI) sensors, such as the single-mode-multimode-single-mode (SMS) structure, exploit interference effects to detect temperature changes with high stability and low strain sensitivity.



Sensor Configuration

Fiber Selection: The core diameter, numerical aperture (NA), and length of the MMF segment influence sensitivity. Larger core diameters increase temperature sensitivity, while higher NA primarily affects strain sensitivity.

SM

S Structure: A short MMF segment is sandwiched between two single-mode fibers (SMFs), forming a compact, low-cost sensor that is insensitive to strain and electromagnetic interference, making it suitable for harsh environments. **Distributed Sensing:** By using a long MMF and analyzing speckle patterns along its length, the system can provide spatially resolved temperature measurements, enabling detection of localized heating or anomalies.

Signal Processing and Temperature Prediction

Recent advances employ deep learning techniques, particularly Convolutional Neural Networks (CNNs), to interpret speckle patterns.

The CN

N can be trained to predict both temperature and the location of heating points along the fiber. Experiments have demonstrated temperature prediction accuracy within ± 1 °C and location prediction precision below 1 cm, even across different types of MMFs. This approach eliminates the need for complex physical modeling and allows real-time monitoring.

Early Warning System Integration

To implement an early warning system: **Threshold Detection:** Define temperature thresholds for critical points along the fiber.

Real-

Time Alerts: Integrate the CNN output with a monitoring interface to trigger alarms when temperatures exceed safe limits. **Data Logging:** Record temperature trends for predictive maintenance and hazard analysis. **Redundancy:** Use multiple MMF paths or segments to ensure reliability in case of fiber damage.

Advantages

High Accuracy: Deep learning-based MMF sensors achieve precise temperature readings. **Strain Insensitivity:** SMS and MMI designs minimize interference from mechanical strain.

Non-

Contact Sensing: Suitable for hazardous or hard-to-access environments. Scalability: Distributed sensing allows monitoring of large areas with a single fiber.

Conclusion

A multimode fiber optic temperature measurement and early warning system combines MMF-based sensing, interference or speckle pattern analysis, and deep learning algorithms to provide highly accurate, distributed, and real-time temperature monitoring. Such systems are ideal for industrial safety, environmental monitoring, and predictive maintenance applications.

Article Content

Deep Learning-Based Multimode Fiber Distributed

We designed an MMF-based temperature-sensing configuration and developed a dual-output Convolutional Neural Network (CNN) for predicting both

Temperature monitoring system for fiber optic multichannel

In this paper, we propose a reflective, intensity-modulated, multi-channel fiber-optic temperature measurement system.

High Sensitivity Temperature Sensing Based on Intermodal Coupling

A high-sensitivity fiber-optic temperature sensor consisting of a cascaded structure of multimode fiber (MMF), tapered seven-core fiber (TSCF) and multimode fiber (MMF) is proposed.

Real-time optical fiber sensing system for multi-point temperature ...

In this paper, a real-time optical fiber quasi-distributed sensing system for multi-point temperature measurement has been presented with detailed design procedure and analysis.

A compatible distributed optical fiber sensing system based ...

Therefore, in this paper, a compatible sensing system with a spatial spectrum multiplexing method is proposed and demonstrated. Based on a new temperature calibration and demodulation

Design and test of multimode interference based optical fiber ...

Practical design of the multimode interference based optical fiber temperature sensors is investigated, and sensing probes are fabricated and tested.

Deep Learning-Based Multimode Fiber Distributed Temperature Sensing

We designed an MMF-based temperature-sensing configuration and developed a dual-output Convolutional Neural Network (CNN) for predicting both the temperature and the position of the

Simultaneous Distributed Acoustic and Temperature Sensing Using a ...

We here deploy the widespread standard multimode fiber (MMF) for simultaneous distributed acoustic and temperature sensing. In particular, we operate the MMF in a quasi-single

Fiber optic high temperature sensor with weak strain ...

We proposed a fiber optic high temperature sensor based on the Mach-Zehnder interference (MZI) structure, which is composed of two lengths of multi-mode fibers (MMFs), a length

Multimode interference based fiber-optic sensor for temperature

A new fiber-optic sensor was demonstrated for temperature measurement using multimode interference effect in single mode multimode single mode (SMS) fiber structure.

Brillouin optical-fiber time domain reflectometry

Abstract We report on Brillouin optical-fiber time domain reflectometry (BOTDR) for distributed temperature or strain measurement along a single-mode optical fiber.

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Optical Fiber Sensors for High-Temperature Monitoring: A Review

High-temperature measurements above 1000 °C are critical in harsh environments such as aerospace, metallurgy, fossil fuel, and power production. Fiber-optic high-temperature sensors are

Design and Implementation of Fluorescence Optical Fiber Temperature ...

Optical fiber fluorescence temperature measurement technology combines optical fiber technology with fluorescence sensing technology, and uses optical fiber to transmit light and the temperature

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