

Postprint: Landslide Monitoring System Based on Ultra-Weak Fiber Bragg Grating Sensing Array Technology

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Abstract

With the rapid development of Internet of Things and intelligent sensing technologies, fiber optic monitoring technology has been widely applied in dam, tunnel, bridge, and urban geological safety applications. To address the practical requirements of landslide monitoring in complex environments that demand large capacity and multi-parameter capabilities, which existing distributed fiber optic sensing technologies cannot satisfy, this study proposes a real-time landslide monitoring system based on ultra-weak fiber Bragg grating (uwFBG) sensing array technology. The system primarily comprises an array sensing monitoring unit, a fiber optic signal modulation and demodulation unit, a data transmission unit, a data processing unit, and an analysis and early warning unit. The system innovatively employs ultra-weak fiber Bragg grating technology featuring narrow bandwidth, high precision, and reflectivity $<0.1\%$, overcoming the physical limitations of conventional fiber Bragg gratings (FBG) and achieving high-density multiplexing of tens of thousands of sensing units on a single fiber. The technological innovations are mainly manifested in three aspects: (1) Development of weak-reflection strain grating array sensing cables with 1 m spacing (including prestressed internal/external fixed-point structures) and temperature sensing cables with 0.5 m spacing. Precision calibration experiments have verified their strain measurement accuracy of $\pm 1\%$ and temperature resolution of 0.1°C , enabling refined strain monitoring of landslides and real-time tracking of rock-soil layer temperatures; (2) Construction of a multi-parameter collaborative monitoring system that employs time-division multiplexing demodulation technology to achieve synchronous parsing of displacement, temperature, seepage pressure, and other parameters, where displacement monitoring is realized through a strain-displacement conversion model across N gauge length sections, achieving spatial positioning accuracy of 0.5 m; development of an intelligent monitoring platform integrating fiber optic signal modulation and demodulation, 4G/5G wireless transmission, and cloud-based data analysis, supporting

real-time processing of fiber optic data and early warning analysis functions. Practical engineering applications in landslide monitoring have demonstrated that the system can accurately locate landslide displacement deformation positions and perceive temperature variations in real time. Its large-capacity, high-precision technical characteristics are particularly suitable for long-term real-time dynamic observation of landslides in complex environments.

Full Text

Preamble

Landslide Monitoring System Based on Ultra-Weak Fiber Bragg Grating Sensing Array Technology

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Abstract

With the rapid development of the Internet of Things (IoT) and intelligent sensing technologies, fiber optic monitoring has found widespread application in dams, tunnels, bridges, and urban geological safety. However, existing distributed fiber optic sensing technologies cannot satisfy the practical demands of landslide monitoring in complex environments that require large capacity and multi-parameter detection. To address this gap, this study proposes a real-time landslide monitoring system based on ultra-weak fiber Bragg grating (uwFBG) sensing array technology. The system comprises an array sensing monitoring unit, fiber optic signal modulation/demodulation unit, data transmission unit, data processing unit, and analysis and early warning unit.

The system innovatively employs ultra-weak FBG technology featuring narrow bandwidth, high precision, and reflectivity below 0.1%, thereby overcoming the physical limitations of conventional fiber Bragg gratings (FBGs) and enabling high-density multiplexing of tens of thousands of sensing units on a single optical fiber. The technological innovations are manifested in three main aspects: (1) Development of weak-reflection strain grating array sensing cables (with pre-stressed internal/external fixed-point structures) at 1m spacing and temperature sensing cables at 0.5m spacing. Precision calibration experiments confirm a strain measurement accuracy of $\pm 1\%$ and temperature resolution of 0.1°C , enabling fine-grained strain monitoring of landslides and real-time tracking of rock-soil layer temperatures. (2) Construction of a multi-parameter collaborative monitoring system that utilizes time-division multiplexing (TDM) demodulation technology to simultaneously resolve displacement, temperature, seepage pressure, and other parameters. Displacement monitoring is achieved through

a strain-displacement conversion model across N gauge segments, achieving spatial positioning accuracy of 0.5m. (3) Development of an intelligent monitoring platform that integrates fiber optic signal modulation/demodulation, 4G/5G wireless transmission, and cloud data analysis, supporting real-time processing of fiber data and early warning analysis functions.

Field applications in landslide monitoring demonstrate that the system can accurately locate landslide displacement deformation and perceive temperature variations in real time. Its large-capacity, high-precision technical characteristics are particularly suitable for long-term, real-time dynamic observation of landslides in complex environments.

Keywords: landslide; ultra-weak fiber Bragg grating; sensing array; Internet of Things; real-time monitoring

Note: Figure translations are in progress. See original paper for figures.

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