Sub-meter scale spatial resolution monitoring in structural health monitoring using DPP-BOTDA

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Ensuring the extended and secure operation of critical infrastructure requires the continuous monitoring of physical parameters to identify potential degradation and defects. Distributed fiber optic sensor (DFOS) technology is a powerful solution for structural health monitoring (SHM) that can provide thousands of sensing points along a single optical fiber. Among various types of DFOS, Brillouin optical time domain analysis (BOTDA) system stands out due to its extensive sensing range of tens of kilometers, making it an ideal for measuring strain and temperature. By analyzing changes in physical parameters of the light within the optical fiber, such as intensity, phase, frequency, it becomes possible to predict structural defects and deterioration. One inherent limitation of conventional BOTDA systems is their reliance on light pulses with durations longer than the phonon lifetime (approximately 12 nanoseconds), which limits the spatial resolution to the meter-scale. This limitation can hinder the detection of subtle structural issues, such as cracks in buildings or leaks in oil and gas pipelines. To overcome this limitation, we introduce the differential pulse width pair (DPP) scheme, which enhances the spatial resolution to sub-meter scales by utilizing pulse pairs with different pulse widths. In this study, we have developed the DPP-BOTDA system, which is designed to fit a standard 19-inch rack. We conducted experiments in simulated scenarios that could realistically occur, capturing Brillouin signals and analyzing the complex changes in physical quantities applied to the optical fiber. This research marks a significant advancement in the field of Structural Health Monitoring, enabling more precise detection and prediction of structural defects and improving the overall safety and longevity of critical infrastructure.