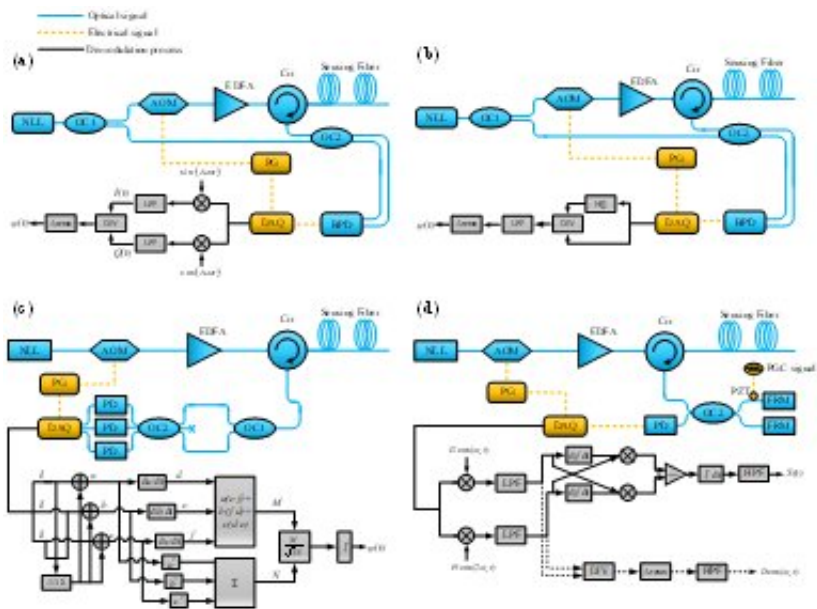


# Advances in distributed fiber optic vibration/acoustic sensing technology

April 4 2022



The setup of DAS- $\Phi$ -OTDR systems with different demodulation methods. (a) heterodyne detection and I/Q phase demodulation; (b) heterodyne detection and Hilbert transform phase demodulation; (c) direct detection and phase demodulation based on 3 $\times$ 3 coupler; (d) direct detection and phase demodulation based on phase generated carrier algorithm. Credit: Compuscript Ltd

A new publication from *Opto-Electronic Advances* reviews advances in distributed fiber optic vibration/acoustic sensing technology.

Distributed fiber optic vibration/acoustic sensing technology utilizes the Rayleigh back-scattered light generated by periodically injecting [laser](#)

[pulses](#) into fiber under test (FUT) to achieve long-range, high spatial resolution vibration detection over the entire length of the FUT. Compared with traditional electrical or mechanical sensors, this technology operates in a fully distributed manner with high sensitivity, remote accessibility and immunity to [electromagnetic interference](#), making it suitable for various application prospects, especially under extreme environmental conditions.

Phase-sensitive optical time-domain reflectometry ( $\varphi$ -OTDR) technology has been rapidly developing since the first fiber optic distributed vibration sensing (DVS) system based on  $\varphi$ -OTDR was introduced in 2005. It was later evolved into distributed acoustic sensing (DAS) technology with the ability to quantitatively analyze acoustic waveforms. On this basis, researchers have conducted extensive research to enhance the sensing performances of  $\varphi$ -OTDR systems, including key performance parameters such as sensing distance, spatial resolution, frequency response range, and event recognition accuracy. Based on its superior long-range and high-resolution distributed sensing capability,  $\varphi$ -OTDR has been widely used in engineering applications in recent years, especially in the emerging fields of seismic wave acquisition, oil and gas resource exploration, pipeline leakage detection, perimeter protection, cable partial discharge monitoring, etc.

In the future, with the development of sensitivity-enhanced fiber optic cable, novel sensing mechanism, efficient signal processing procedures, and accurate vibration event recognition algorithms,  $\varphi$ -OTDR-based DVS/DAS will show great potential for a broad range of commercial applications, including distributed fiber shape sensing and geological exploration. Finally, this article discussed the prospects and challenges of the future development of  $\varphi$ -OTDR-based DVS/DAS technology.

The research groups of Professor Liyang Shao from Southern University of Science and Technology, China and Professor Feng Wang from

Nanjing University, China jointly reviewed the research progress of  $\varphi$ -OTDR-based fiber optic DVS/DAS technology and its emerging applications. Firstly, the sensing principles of DVS- $\varphi$ -OTDR based on Rayleigh backscattered light intensity demodulation, and DAS- $\varphi$ -OTDR system based on phase demodulation were analyzed. The DAS phase demodulation techniques, such as heterodyne detection scheme with I/Q demodulation, heterodyne detection scheme with Hilbert transform, direct detection scheme based on 3 x 3 coupler and direct detection scheme based on phase-generating carrier algorithm, were introduced and compared. Then, the performance enhancement methods were discussed and analyzed in detail for the key sensing parameters of  $\varphi$ -OTDR systems, including maximum sensing distance, signal-to-noise ratio, vibration frequency response range, [spatial resolution](#), and accuracy of vibration pattern recognition.

This review further summarizes the engineering applications of  $\varphi$ -OTDR systems in various fields, involving geological exploration, pipeline protection, perimeter security, and cable partial discharge detection, as well as special applications such as shape sensing, gas concentration sensing, and pest infection detection.

**More information:** Shuaiqi Liu et al, Advances in phase-sensitive optical time-domain reflectometry, *Opto-Electronic Advances* (2021). [DOI: 10.29026/oea.2022.200078](https://doi.org/10.29026/oea.2022.200078)

Provided by Compuscript Ltd

Citation: Advances in distributed fiber optic vibration/acoustic sensing technology (2022, April 4) retrieved 9 June 2023 from <https://phys.org/news/2022-04-advances-fiber-optic-vibrationacoustic-technology.html>

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