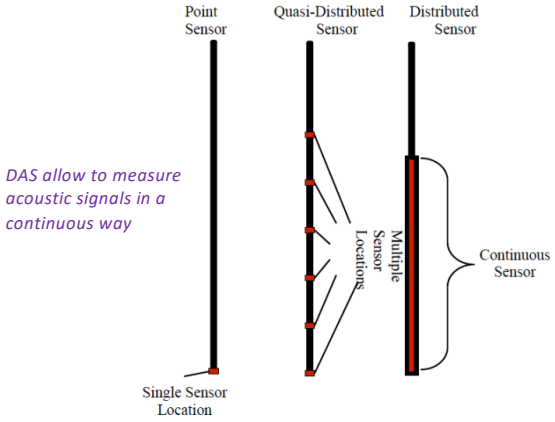
App Note: DLS-07

Ultra-narrow Linewidth Lasers for Distributed Acoustic Sensing (DAS) applications

1. Introduction on Distributed Acoustic Sensing

1.1 Distributed sensing refers to techniques that allow measuring a physical quantity not only at a single point or at multiple points, but in a continuous manner along a designated media. In the case of Distributed Acoustic Sensing (DAS), optical fibers (most often standard telecom fibers) are used to measure acoustic signals.



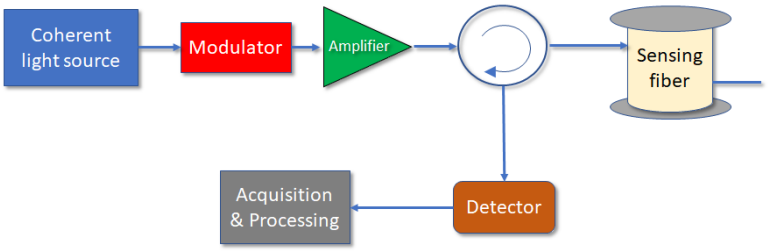
DAS allow to measure acoustic signals in a continuous way

1.2 It is equivalent to having thousands of geophones closely positioned to each other that can records vibrations originating from a wide variety of sources (seismic waves, idling engine, people displacement, response from mechanical stimulus….)

2. Operating principle of DAS

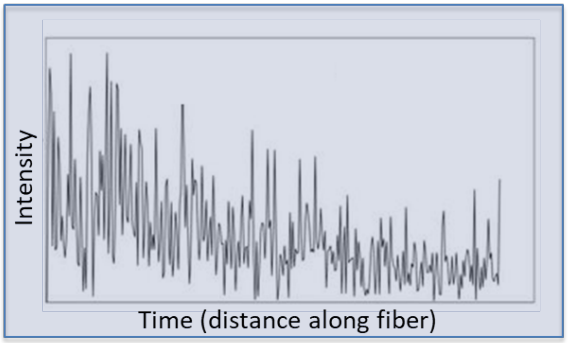
2.1 DAS is based upon a well-established and understood coherent Optical Time Domain Reflectometry (c-OTDR) technique that makes use of density and refractive index variations at the microscopic level in optical fibers.

This method consists on sending a pulse of coherent light into an optical fiber and collecting the returning back-scattered signal. Interference of Rayleigh scattered light from multiple scattering centers within the fiber leads to a speckle-like pattern that depends on the phase difference between the superposing light waves. This pattern is extremely sensitive to length changes within the fiber since a few tens-of-nanometers difference causes a considerable change of phase for light.



Basic measurement apparatus of a DAS system

The amplitude of the signal plotted vs. time (equivalent to the return time-of-flight) will exhibits peaks and troughs. If the light properties are not changing, this totally random pattern is remaining unchanged until external stimulus the is causing strain in the fiber.



Typical pattern of DAS signal

3. Applications of DAS

DAS can be used wherever acoustic information needs to be measured in real time along large distances ranges.

Main DAS applications:

- Pipeline monitoring and control
- Perimeter intrusion detection systems
- Power & Subsea cable monitoring
- Railways and trains traffic monitoring
- Geophysical/Seismic surveys
- Fire detection

ConocoPhillips deploys DAS-based pipeline monitoring system in Alaska for preventing corrosion-related leakage

The main applications are found in the Oil & Gas industry for Pipelines control and monitoring up to 125km, geophysical data acquisition along wells during prospecting seismic surveys and hydraulic fracturing monitoring.

In Perimeter surveillance of sensitive sites such as airport, nuclear plants or military bases where vibrations caused by intruders can be detected and located in real time.

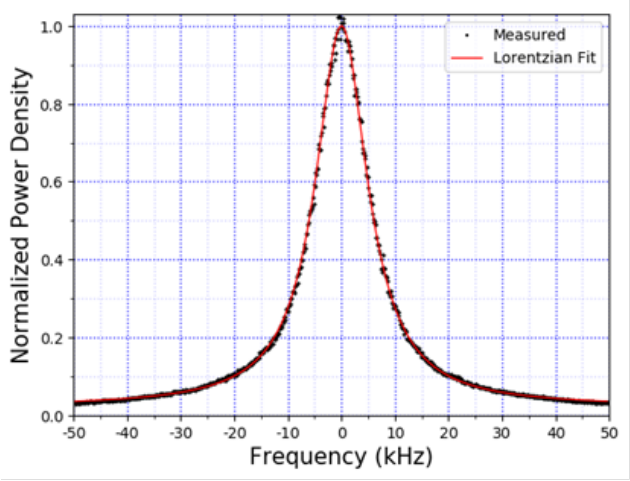
It is also used in civil engineering, in buildings, bridges and along railways, to detect earthquakes, equipment damages or malfunctions as well as for monitoring cables and detecting fire.

4. Light source requirements of DAS

As a fundamental part of any DAS systems, the light source must fulfill certain requirements:

Linewidth and phase noise:

For interferences to occur, the laser coherence length must be greater than the maximum distance separating two scattering centers which is the length of fiber probed by the laser pulse. In typical systems, coherence length of few hundred meters are used, corresponding to optical linewidth of few hundred KHz.



Linewidth measurement on BF series unit

Wavelength stability and tunability:

A typical DAS unit will contain a variety of optical components such as modulator, amplifiers and filters. For optimal performance, the laser wavelength must often times be tuned to a particular value and remain perfectly stable to ensure quality measurements.

Output power stability:

Rayleigh backscatter signal is phase and amplitude sensitive. For DAS systems to perform well and be able to detect acoustic signals over a wide range of frequency, the stability of the output power is pinnacle.

5. Denselight Products offering for DAS

For the last 20 years, Denselight semiconductors have been offering a range of ultra narrow linewidth laser designed for applications in optical metrology & instrumentation and optical gas & chemical sensing, which are perfectly suitable for DAS applications.

BF12 unit used in DenseLight's customer DAS applications

The DL-BF9/BF10/BF11/BF12 series is complete with a DenseLight 14-pin BTF package laser, integrated laser driver and temperature controller. It is available over a wide wavelength range across the O, E, S, C and L bands, and can be customized with various options to meet your specific needs.

	Requirements	Denselight specifications
Output power	>5mW	10-20mW
Wavelength	1530-1560nm	1260-1670nm
Wavelength stability	> +/-5pm	> +/-1pm
Linewidth	<500MHz	10-50KHz
RIN	-120dB/Hz	-150dB/Hz
SMSR	>30dB	>35dB
Fiber type	SM or PM	SM and PM
PER[1] (PM version)	-15dB	-18dB
Operating temperature range	0 to 50degC	-5 to 50degC
Mode hop free operation	✓	✓
Telcordia GR-468-qualification	✓	✓
RoHS compliance	✓	✓

DenseLight BF series vs Typical DAS applications requirements