

DITEST™ - FIBER OPTICS DISTRIBUTED TEMPERATURE & STRAIN SENSING



INTRODUCTION TO DITEST SENSING

Omnisens introduces DITEST (Distributed Temperature & Strain) sensing: an innovative development in distributed sensing based on fiber optic technology. The DITEST sensing technique enables the measurement of temperature and strain using the same, or separate, sensors, in an ever-increasing range of applications and industries, setting new standards of accuracy and reliability, and over longer distances than ever before.

Distributed fiber optic sensing overcomes the inherent limitations of traditional measurement technologies (thermocouples, strain gauges) and enables monitoring solutions with unrivalled advantages for the protection of people and critical assets, especially when monitoring in inaccessible or inhospitable environments. Optical fiber is cheap, light, pliable, and immune to electromagnetic interference (EMI), which makes it a cost-effective, flexible and an inert sensor medium.

WHAT IS DISTRIBUTED SENSING?

The term Distributed Sensing refers to the use of a fiber optic as a linear sensor which provides valuable measurement information from all along the fiber itself. The measurement is based on the analysis of back-scattered light when a laser pulse travels down the optical fiber.

The fiber is integrated in a valuable asset (structure, pipeline, cables, etc.) in a dedicated cable. A single optical fiber can replace thousands of traditional single-point sensors, providing a significant reduction in installation, calibration, and maintenance costs. In addition, assets can now be monitored where previously this was impractical due to their size, complexity, location or environment.

OMNISENS DITEST FEATURES

- **Versatile system for temperature and/or strain with temperature compensation.**
- **Spatial resolution from 0.5 m for temperature and strain.**
- **Long range measurement of up to 30 km¹ per channel, with a spatial resolution of better than 2 m.**
- **Measurement resolution from 0.1°C (Temperature) or 2 microstrain (Strain).**
- **Optional modules increase the range to 250 km, enable remote monitoring and provide flexibility of system design.**
- **Fast acquisition time - less than one second for dynamic monitoring to minutes for high resolution measurements**
- **Large optical budget available for installations with fiber attenuation or losses.**
- **Reliable performance even where hydrogen penetration or radioactivity can cause fiber darkening.**
- **Fast and reliable measurements, up to 10 times faster than some other Brillouin and most Raman techniques.**
- **Abundance of user definable configurations to optimize measurement for each application**

¹ From a single DITEST, longer distances can be measured, with reduced spatial resolution (e.g. 5 m spatial resolution at 40km).

THE PHYSICS OF DISTRIBUTED SENSING TECHNIQUES

Distributed sensing is based on the analysis of backscattered light emitted when a light pulse is transmitted down an optical fiber. The backscattering is due to interaction with density fluctuations and molecular vibrations.

Backscatter comprises three significant forms relevant to distributed sensing (Fig. 1):

- **RAYLEIGH SCATTERING** – produces the largest magnitude of backscatter at the same frequency as the incident light.
- **BRILLOUIN SCATTERING** – produces backscatter of lower intensity than Rayleigh, due to thermally excited acoustic waves (acoustic phonons), but exhibits a frequency shift of around 10 GHz (0.1 nm at 1.5 micron wavelength). The Brillouin **frequency shift** is directly related to both temperature and strain of the fiber.
- **RAMAN SCATTERING** – produces backscatter of the lowest intensity, due to thermally excited molecular vibrations (optical phonons), and exhibits a frequency shift of up to 13 THz (100 nm at 1.5 micron wavelength). The **intensity** of Raman scattered light is dependent on the local temperature of the fiber

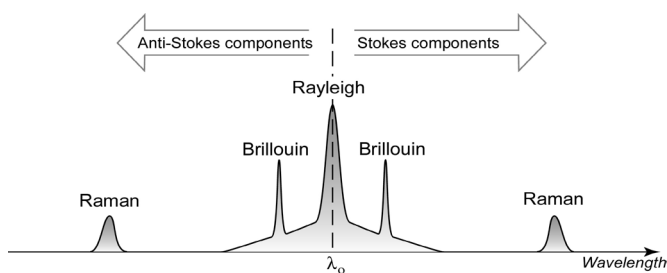


Fig. 1: Typical spectrum of the backscattered light from a monochromatic source (single wavelength λ_0) propagating in an optical fiber.

The scattering of the light occurs at low energy levels, and increases with the optical energy present in the fiber. Omnisens' technique **stimulates** the scattering process by launching a counter-propagating lightwave in the fiber, giving a uniquely **enhanced measurement performance**.

ADVANTAGES OF BRILLOUIN TECHNIQUES

The Omnisens DITEST exploits the sensitivity of the Brillouin frequency shift for temperature and strain sensing applications.

The technique uses standard low-loss single-mode optical fibre offering several tens of kilometres of distance range and a compatibility with standard telecommunication components.

Brillouin scattering can be optically stimulated leading to the greatest intensity of the scattering mechanism and consequently an improved signal-to-noise ratio.

Brillouin frequency-based technique is opposed to intensity based techniques such as Raman and is inherently more accurate and more stable in the long term, since intensity-based techniques suffer from a high sensitivity to drifts.

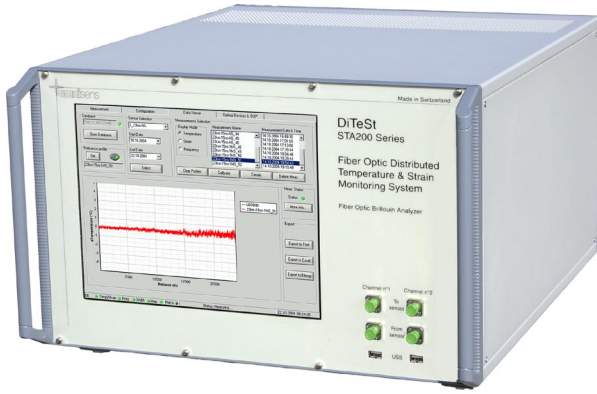
THE OMNISSENS DITEST IS ESPECIALLY SUITABLE FOR APPLICATIONS REQUIRING SPEED, DISTANCE OR A HIGH OPTICAL BUDGET.

PRINCIPLE OF OPERATION

Data from the backscattered signal is processed using time and frequency domain analyses.

The DITEST uses a single laser to generate the two signals used to stimulate backscattering (SBS): an optical pulse (or pump) and a continuous wave (CW) optical signal, known as the probe signal. Using only a single laser gives stability, due to self compensation of drifts.

When the frequency difference of the two signals reaches the Brillouin frequency, a resonance condition is established, leading to the stimulation of Brillouin scattering. This stimulation induces an energy transfer from the pulse to the probe signal and an amplification of the probe signal.



DEFINING PERFORMANCE FOR DISTRIBUTED SENSING

The definition of performance specifications for distributed sensors is more difficult than for traditional point sensors since the performance depends on a combination of related measurement parameters. For example, accuracy depends on the spatial resolution, acquisition time, distance range or cumulated loss prior to measurement location.

The graph in Figure 3 shows how DITEST performance parameters may be evaluated.

DISTANCE RANGE OR SPATIAL RANGE corresponds to the maximum fiber sensor length over which the instrument's stated performances are met.

SPATIAL RESOLUTION is the instrument's ability to measure accurately two adjacent locations submitted to different temperature/strain conditions. The spatial resolution is directly related to the optical pulse width or the distance illuminated by the pulse at a given time (10 ns corresponds to 1 m in the fiber).

Based on this definition, a given temperature/strain that spreads over a distance greater than the spatial resolution is measured with 100% of instrument accuracy. If a local temperature/strain change occurs on a distance smaller than the spatial resolution set on the instrument, the change will not be measured with the full accuracy.

The DITEST spatial resolution is configurable from 0.5 m to 10 m. In practical applications, the spatial resolution is normally set to values ranging from 1 m to 3 m.

DISTANCE RESOLUTION is determined by the number of points along the sensor length and is given in meters. The

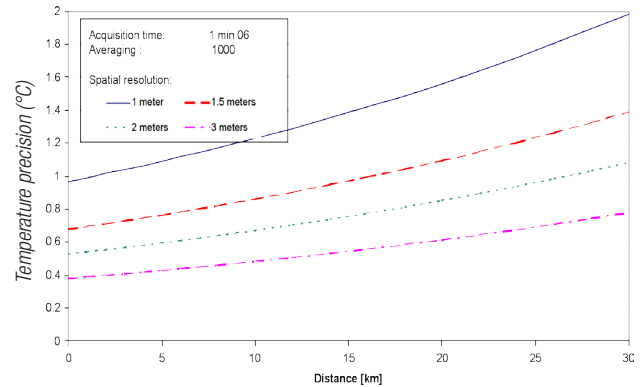


Fig 3: Actual instrument performance in terms of resolution (°C) for different measurement settings and for standard optical fiber (attenuation < 0.25 dB/km)

DISTANCE PRECISION corresponds to the precision of the location of a measured point. It depends on the time acquisition and on how accurately the index of refraction and cable-lay loss of the fiber are known.

MEASUREMENT UNCERTAINTY is a measure of the agreement between measurements of the same property with a known value under identical, or substantially similar, conditions.

MEASUREMENT RESOLUTION is associated to a measure of the short term repeatability and is evaluated as a function of distance for a given spatial resolution and acquisition time, as well as specified fibre attenuation

THE ADVANTAGES OF OMNISSENS DITEST

The Omnisens DITEST offers significant advantages over other distributed sensing methods:

RELIABLE TEMPERATURE/STRAIN MEASUREMENT - the DITEST is able to measure either temperature or strain, or both, using the same optical fiber. Alternatively, when installation conditions dictate, temperature and strain can be measured using separate fibers operating on different channels of the same instrument. For temperature monitoring, the optical fiber is installed within protective loose tubing thereby preventing strain conditions from having a significant effect on temperature measurements. For strain monitoring, a dedicated strain sensor is required, in order to transfer strain to the fiber.

EXCELLENT PERFORMANCE HIGH RESOLUTION OR FAST ACQUISITION APPLICATIONS - adjustable probe signal intensity solves the problem of lossy fibers or attenuation associated with spontaneous scattering techniques.

SUPERIOR RELIABILITY, ACCURACY AND REPEATABILITY automatic setting of optical intensities are user-configurable to optimise the performance in various measurement conditions.

FASTER MEASUREMENT TIMES - measurements using stimulated Brillouin scattering require less averaging than other techniques for maintained performance (30 km of fiber can be measured at highest performance in 1 to 2 minutes typically.)

DYNAMIC STRAIN MONITORING Stimulated Brillouin scattering makes possible dynamic strain measurements with updating time down to <1 second.

HIGH DYNAMIC RANGE - measurement performance can be maintained with up to 20 dB of attenuation.

LONGER RANGE MEASUREMENTS - up to 30 km range per channel, with a spatial resolution of better than 2 m. Optional channels and modules may be fitted to allow measurement of up to 250 km.

PROVEN MEASUREMENT TECHNOLOGY - Omnisens systems are built using proven components and have been developed with the emphasis on measurement reliability and accuracy.

FLEXIBLE SOLUTIONS - the unique optical signal processing technique incorporated in DITEST brings a high level of flexibility to suit a wide range of applications and environments.

COST-EFFECTIVE FIBER OPTIC SENSOR - the physical attributes and cost-effectiveness of optical fiber make it particularly suited for long distance applications such as monitoring pipelines, power cables and overhead lines.

SUITABLE FOR DEMANDING ENVIRONMENTS - different types of optical fiber sensor for both temperature and strain monitoring are available to meet the demands of a wide variety of installations.

For example, sensors with enhanced crush resistance and rodent damage protection are available for subterranean, submarine and tunnel environments.

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