



Temperature monitoring using Distributed Fiber-Optic Sensors – an introduction

Introduction

The Fiber-optic Distributed Temperature Sensing (DTS) method using the Raman-effect was developed at the beginning of the nineteen eighties at Southampton University in England, UK. The DTS method is based on optical time-domain reflectometry (OTDR) and uses a technique derived from telecommunication cable testing.

The Fiber-optic DTS method is a relatively new system for temperature monitoring using optical fiber instead of thermocouples or thermistors, as has typically been the case in the past. DTS represents a powerful breakthrough in temperature measurements. Obtaining thousands of accurate, high-resolution temperature measurements is now cost-effective.

SensorTran, Inc. makes a robust and compact DTS system that mounts in a standard 19" rack and can monitor up to 30 kilometers of fiber with a temperature resolution of 0.1°C (RMS) and a spatial resolution of 1 meter. The full specifications are contained in the latest Product Data Sheet available upon request or on our web-site www.SensorTran.com

Fiber-optic distributed temperature monitoring is of a particular advantage in several common situations:

- 1) **When there are a large number of sensors to be placed.** If it is necessary to place a lot of temperature sensors for complete monitoring, then the ease of installation of fiber-optic DTS becomes apparent. A single optical fiber can replace many point sensors, so all that is necessary is to route the fiber so that it provides the necessary measurement coverage and density.
- 2) **When there is no *a priori* knowledge of sensor placement.** When the preliminary engineering is performed on a project, it is not always possible to determine the correct location for temperature sensors. The high spatial resolution and long range of a fiber-optic sensor allows the operator to select which parts of the fiber to monitor after the project is complete.
- 3) **When electrical temperature monitoring is impractical.** In a situation where there is a large amount of electro-magnetic noise, the data being read from thermocouples and thermistors can be corrupted. However the data being read by the DTS is purely optical, and thus immune to contamination in this kind of environment.
- 4) **When electrical temperature monitoring is unsafe.** There is a risk of sparking inherent in all electrical systems. If the atmosphere in the area being monitored is in danger of becoming volatile, then the fact that a fiber-optic DTS does not present a spark hazard can be a significant safety advantage.

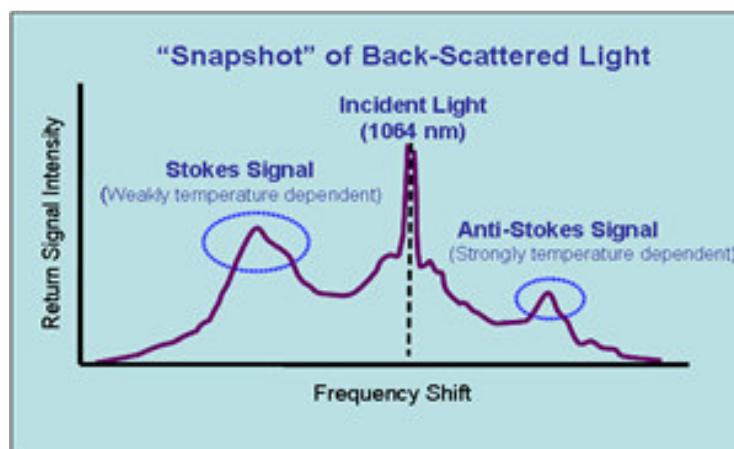
DTS Fundamentals

In the DTS technique, a pulse laser is coupled to an optical fiber through a directional coupler. Light is backscattered as the pulse propagates through the fiber, owing to changes in density and composition as well as to molecular and bulk vibrations. In a homogeneous fiber, the intensity of the backscattered light decays exponentially with time.



Because the velocity of light propagation in the optical fiber is well known, the distance can be determined from the time-of-flight of the returning backscattered light. The backscattered light consists of different spectral components due to different interaction mechanisms between the propagating light pulse and the optical fiber.

These backscattered spectral components include Rayleigh, Brillouin, and Raman peaks or bands. The Rayleigh backscattering component is the strongest due to density and composition fluctuations and has the same wavelength as the primary laser pulse. The Rayleigh component controls the main slope of the intensity decay curve and may be used to identify the breaks and heterogeneities along the fiber. The Rayleigh component is not sensitive to temperature.



The Brillouin backscattering components are caused by lattice vibrations from the propagating light pulse. However, these peaks are spectrally so close to the primary laser pulse that it is difficult to separate the Brillouin components from the Rayleigh signal.



The Raman backscattering components are caused by thermally influenced molecular vibrations from the propagating light pulse. Thus, their intensity depends on temperature. The Raman backscattered light has two components that lie symmetric to the Rayleigh peak: the Stokes peak and Anti-Stokes peak (a basic diagram of Raman spectral components can be seen on our web-site).

The intensity of the Anti-Stokes peak is lower than that of the Stokes peak, but is strongly related to temperature; whereas the intensity of the Stokes peak is only weakly related to temperature. By calculating a ratio of the Anti-Stokes to Stokes signal intensities, an accurate temperature measurement can be obtained. Combining this temperature measurement technique with distance measurement through time-of-flight of light, the DTS provides temperature measurements incrementally along the entire length of the fiber.

DTS Equipment

SensorTran's DTS Unit consists of a rack-mounted single-board industrial computer. The computer is fully self-contained, with both LAN and modem connections to allow easy transfer of the temperature data to a remote server. The data can be analyzed locally using SensorTran's software.

The Distributed Temperature Sensor itself consists of two cards that reside on the PCI bus inside the computer. One of them handles the optics and analog electronics, while the other handles the digital aspects of the data collection. Since the Raman backscatter is a low-probability event, it is necessary to take data from hundreds of thousands of laser pulses in order to separate the signal from the inherent noise.

The high number of laser pulses means that each temperature measurement takes approximately less than a minute to complete. If lower temperature resolution is acceptable, this time can be reduced. The laser light can also be multiplexed using a standard fiber-optic switch. This can allow the monitoring of up to fifty different fibers in succession.

Once the data has been collected, it is transferred to permanent storage and converted from raw signal levels to a distance vs. temperature plot. Further processing can be performed at this point to reduce the dataset to the elements that are of interest to the user.



Installation of Optical Fiber

Standard multimode communication optical fiber can be used without any modification. To support installation and operational requirements, the optical fiber can be obtained with a variety of coating and packaging options. Various methods have been developed for the installation of fiber, depending on the application.

Conclusion

Fiber-optic Distributed Temperature Sensors represent a practical new way to monitor temperatures over long distances in harsh environments with high resolution and repeatability. It provides the opportunity for users to gather significantly more and better temperature data in many applications where it has not been possible until now.

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