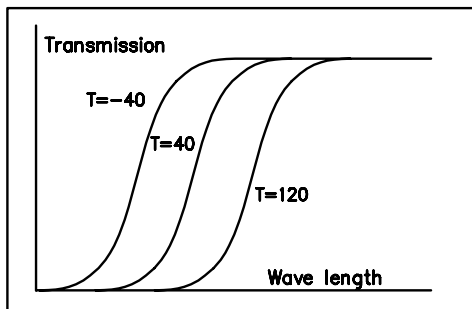


TECHNICAL NOTE

AN OVERVIEW OF FISO'S FIBER OPTIC DIRECT WINDING TEMPERATURE MEASUREMENT SYSTEM FOR HIGH VOLTAGE TRANSFORMERS

The principle

FISO's fiber-optic temperature sensors, *for direct winding temperature measurement in high voltage transformers*, are based on white light absorption/transmission by a GaAs (gallium arsenide) semiconductor. The effects of temperature variations on this semiconductor are well known and predictable. As the temperature of the semiconductor increases, the semiconductor's transmission spectrum (i.e. the light that is not absorbed) **shifts** to higher wavelengths. At any given temperature, transmission jumps from essentially 0% to 100% at a specific wavelength. This jump is called the **absorption shift**, and the relationship between the specific wavelength where the absorption shift takes place and temperature is predictable.



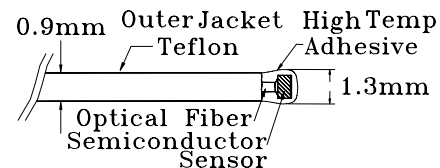
Why does this shift occur? The physical explanation for this phenomenon is found in the variation in the semiconductor's energy **band gap**. This "gap" refers to the energy required to bump the electrons in the material into an **excited state** (as opposed to the relaxed, **steady state**). As more energy enters the semiconductor, in the form of heat as its temperature rises, this gap gets narrower—less additional energy is needed to excite an electron.

The photons (particles of light) entering the semiconductor are what actually excite the electrons. If a photon is carrying enough energy to get an electron across the gap, it will be **absorbed**. If it is not carrying enough energy, then it will be **transmitted**. The shorter a photon's wavelength is, the more energy it carries. Since the band gap narrows as the semiconductor temperature increases and less energy is needed to jump across the gap, photons with less and less energy (longer and longer wavelengths) will be absorbed "by the band", as they say. The effect is to move the absorption shift to longer wavelengths.

Consequently, measuring the position of the absorption shift gives a measure of the semiconductor's temperature. It is important to note that technology isn't intensity dependent but wavelength dependent.

The Temperature Sensor

The *Nortech* system is based on **direct contact** temperature measurement. Traditional temperature sensors like thermocouples and RTDs (resistance temperature devices) work on the same principle. In other words, the semiconducting material must be touching the object or immersed in the liquid or gas to be measured. The more intimate the contact and the smaller the thermal mass of the sensing tip, the faster the semiconductor will respond to changes in temperature. We then want to be able to deliver light to the semiconductor and measure what is absorbed. That is the function of the optical fiber.



A tiny semiconductor of GaAs semiconductor is bonded to one end of a well polished optical fiber. On one side of this semiconductor, a reflective **dielectric** film has been deposited. Dielectric means it does not conduct electricity; all of the materials share this property ("high dielectric strength"), which is one of the principal advantages of our sensor technology over traditional temperature sensors like thermocouples and RTDs (which use wires to convey an electrical signal).

The length of the optical fiber is covered with a PTFE (Teflon) sheath, making it very resistant to aggressive chemical environments as well as an additional perforated PTFE sheath (spiral wrap) for added ruggedness and even oil circulation. The entire end assembly (semiconductor and end of the fiber) is then embedded in high temperature adhesive to protect the sensor (the semiconductor) from chemical and mechanical aggression. Consequently, the only barrier to direct contact is this adhesive.



FISO Technologies, Inc.

500 St-Jean-Baptiste Avenue, Suite 195, Québec, QC, Canada, G2E 5R9

Phone : 418-688-8065 Fax : 418-688-8067

E-mail : sales@fiso.com WEB : www.fiso.com

The Signal Conditioner

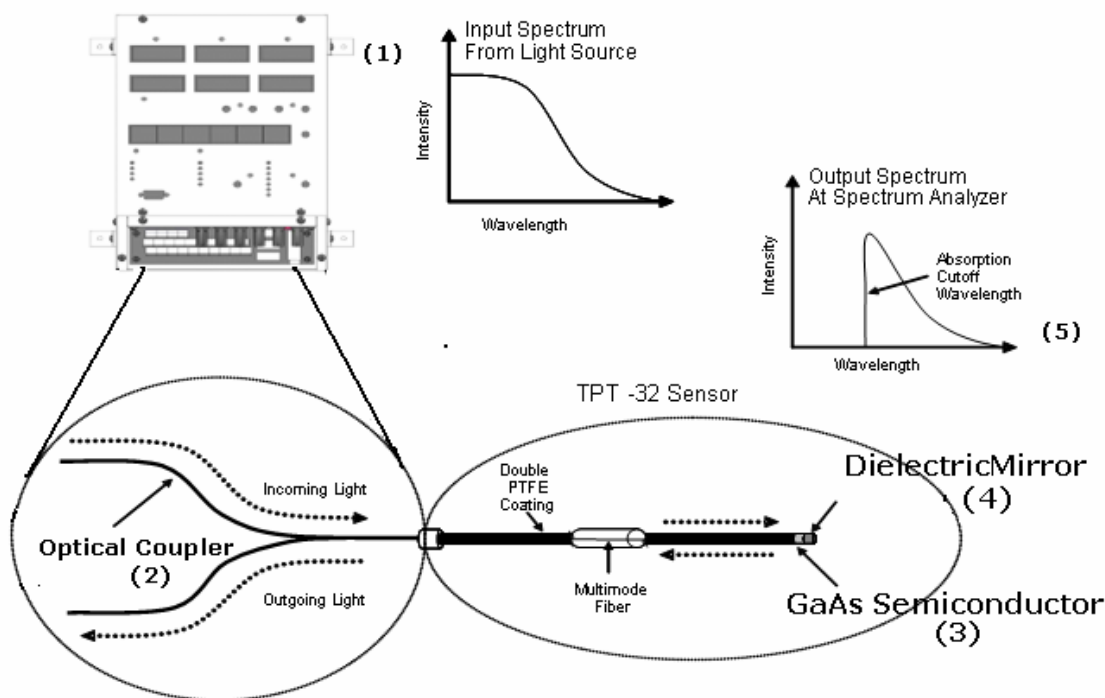
Numbers in the following description refer to the block diagram below. A **white light source (1)** located inside the signal conditioner injects light into one of the branches of a fiber optic coupler **(2)**. This light travels down the sensor's optical fiber to the semiconductor **(3)** where some of the wavelengths are absorbed. Unabsorbed light is reflected by the dielectric mirror **(4)** and returns down the sensor to the coupler or switch, where it is directed to a **spectrometer (5)**.

The position of the absorption shift is determined using a proprietary signal analysis algorithm and is then correlated to temperature. The computation of the absorption shift does not depend on signal intensity for this particular instrument; essentially only the color of the light is of interest. Consequently, the various factors that contribute to attenuation on optical fibers (fiber length, number and quality of connections, fiber diameter and composition, bending) do not impose any serious constraints on our system. Furthermore, since the semiconducting semiconductor's response is

universal, all our sensors are interchangeable with no need for calibration of the instrument or entry of special codes when swapping sensors. FISO's approach gives reliable, repeatable temperature measurements without the errors that may result from a loss of power in the connectors or a curve in the optical fiber.

Why does the system need to know the spectrum of the source? If for example, the system knows that the source emits equally in the red and blue regions of the spectrum and the spectrometer is reading equal intensity in both the red and the blue regions, then the system knows that the semiconductor is absorbing equally in both regions. On the other hand, if the source emits strongly in the red region and weakly in the blue region and the spectrometer is still reading equal intensity in both, then the system knows that there must be more absorption in the red region than in the blue one. In other words, the instrument uses its knowledge of the spectrum of the source to linearize the signal from the optical sensor.

Nortech Signal Conditioner



FISO Technologies, Incorporated reserves the right to make any changes in the specifications of their products without prior notice.
DOC: MC-00133 R



FISO Technologies, Inc.

500 St-Jean-Baptiste Avenue, Suite 195, Québec, QC, Canada, G2E 5R9

Phone : 418-688-8065 Fax : 418-688-8067

E-mail : sales@fiso.com WEB : www.fiso.com