APPLICATION NOTE

Is Optical Displacement Sensing for You?

Introduction

Non-contact displacement and vibration sensors are often used as a practical alternative to contact type devices. Non-contact optical position sensors are, in many cases, the only viable method for difficult sensing measurements. Several advantages of these devices are that they do not disturb the target, are immune to electromagnetic interference (EMI), are available in small sensor packages and may be used in tough, harsh or otherwise inaccessible locations. Some of the typical measurement conditions which may dictate the use of a non-contact are as follows:

- Little or no force can be applied to the target because it may cause unacceptable deformation of the sample being tested.
- The target is moving past the measurement point at a high rate of speed.
- Vibration levels are too high to permit a contact device to follow the true motion.
- The part may be damaged when contacted by the sensor.
- Surface discontinuities exist which would cause unacceptable bounce or chatter of a contact device.
- The part may be located in a temperature environment unsuitable for a contact transducer.

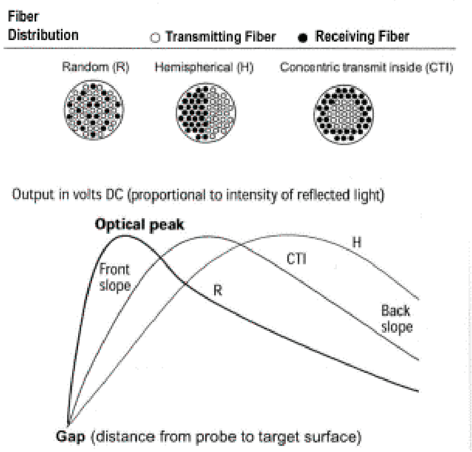
Fiber Optic Sensors

These sensors operate by monitoring the amount of light reflected from the target surface being measured. They are able to precisely determine parameters such as displacement, vibration, position and gap and are frequently used to determine surface condition. A variety of sensor configurations provide sub-micron resolution and/or a large measurement range. MTI's Fotonic ™ sensors provide accurate measurements on almost any type of surface or material including metallic, plastic, glass and ceramics. They can also operate in water or oil, however, a slight sensitivity change occurs that can easily be accounted for. For confined spaces, the optical fiber probes can be bent or prisms can be attached to redirect the direction of light. Armored cable and non-metallic jackets coupled with ceramic tips extend the usefulness of the equipment into production and high vacuum applications. The MTI-2100 Fotonic Sensor System (Photo 1) consists of a mainframe signal processor/controller which accepts up to two fiber-optic probe plug-in modules. The plug-in modules incorporate a seven-position low-pass filter and a three-position high-pass filter for improved signal to noise ratio. Typical frequency response of the sensor is 150 kHz, however, special systems are available that can exceed 1 mHz.

Photo 1: MTI-2100 Fotonic Sensor System

Sensor Operation

Figure 1 Probe configurations



Each MTI-2100 Fotonic probe contains a set of light transmit and receive fibers, which can be arranged in three different configurations (random, hemispherical or concentric as shown in Figure 1).

A tungsten halogen lamp feeds light down the transmit fibers, where it exits the probe tip and hits the target. Light that is reflected from the target is captured by the receive fibers and transmitted to the MTI-2100. The light intensity is monitored, which is proportional to the distance between the probe tip and the target being measured. At contact, no light is exiting or received by the fibers, giving an output signal of zero. As the probe-to-target distance increases (see Figure 2 and Figure 3), increasing amounts of light are proportionally captured by the receive fibers. The result is a very sensitive, linear output response (Figure 4 Front Slope) from the MTI-2100. As the distance is further increased, the amount of light received approaches the maximum or "optical peak." After the "optical peak" is reached, a continued increase in probe gap will proportionally reduce the amount of light received. This results in a sensitive, linear output response (Figure 4 Back Slope) with a large measurement range and standoff distance.

Figure 2 Reflected light intensity is low, close to target

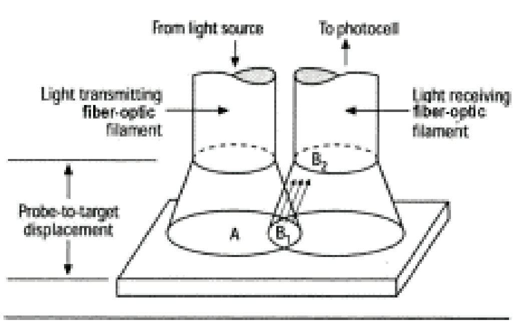


Figure 3 Maximum reflected light intensity

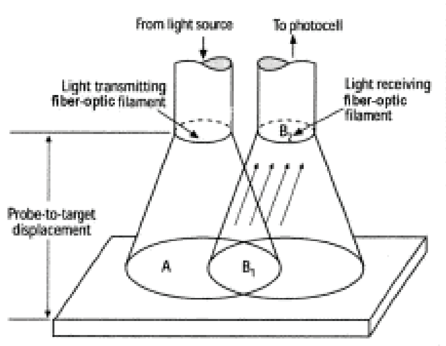


Figure 4 Calibration curve, showing front slope and back slope

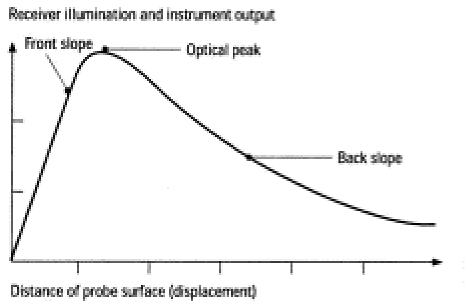
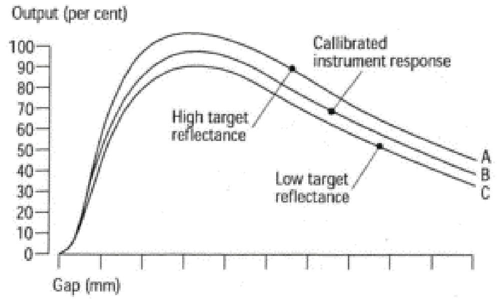


Figure 5 Light reflectance response curves



To obtain consistent sensitivities (slopes) on the Front and Back Slope the instrument is calibrated to each specific target surface (shown in Figure 5) by setting the position of the fiber optic probe so that it produces the maximum reflected light signal (optical peak) and pressing the calibration button. The instrument will then automatically adjust the intensity of the light source until the reflected light signal reaches the calibration set point of 10 V dc.

Other versions of the MTI-2100 Fotonic Sensor provide completely automatic, real time reflectance compensation by use of special dual receiver fiber optic probes and ratiometric signal processing. In addition to the reflective sensor heads, thru-beam sensors using fiber optics to shape the light field are also available. The edge of the object being measured is placed in the light path and acts as a shutter to directly modulate the received intensity, thus providing reflectance independent sensing.

Sensor Selection

Three different fiber arrangements are available, random (R), hemispherical (H) and concentric transmit inside (CTI), as shown in Figure 1. The random configuration, in which the transmit and receive fibers are randomly dispersed, provides the highest sensitivity, however, the measurement range is typically reduced. If a larger range is required, the hemispheric configuration is selected. The CTI configuration is a compromise between the R and H models.

Laser Triangulation Sensors

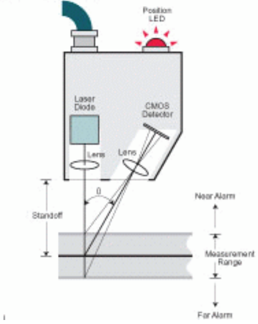
For applications requiring a longer standoff distance a laser triangulation displacement system, such as the Microtrak™ 7000 (Photo 2), may be used. Laser triangulation offers a larger measurement range and does not need to be calibrated to each surface it measures. The red, visible laser spot simplifies beam alignment which proves especially useful when measuring small targets.

Photo 2: Microtrak 7000 Laser Triangulation System

Operating Principle

A laser triangulation system consists of a laser head and controller. Each sensing head contains a solid-state laser light source and a PSD or CMOS detector. The laser beam is focused on the target surface and a portion of the beam is reflected through the receive optics onto a detector. As the target moves the laser beam proportionally moves on the detector as shown in Figure 6.

Figure 6 Laser Operating Diagram



The signal from the detector is used to determine the relative distance to the target. This information is then provided at the analog output and digital interface as well as on a digital display. A single sensing head can be used to measure displacement, runout or vibration. When two sensors are used, difference or thickness measurements can be made. Target reflectivity changes can influence the measurement results so sensors typically incorporate compensating automatic gain circuitry. Figure 7 illustrates two basic laser sensors. The diffuse head is designed to measure matte type finishes which evenly disperse the laser signal in all directions. A portion of this reflection is focused onto the position detector to determine target position. Specular laser heads are used to measure highly reflective targets like polished and mirrored finishes that reflect all of the laser signal to the position detector.

Figure 7 Laser sensor arrangements

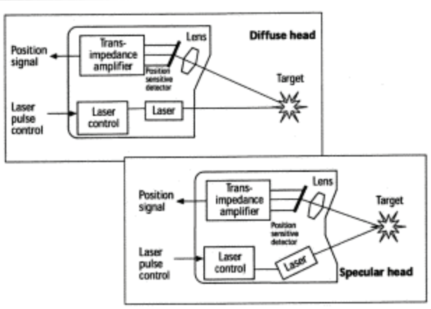
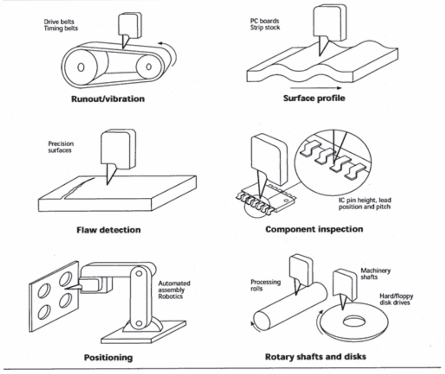


Figure 8 Typical laser applications



Practical uses for these devices are rapidly expanding. Figure 8 illustrates several key applications for non-contact laser displacement sensors. From manufacturing and development applications in automotive and machinery to production line measurements in the pulp/paper, electronics and semiconductor markets, the flexibility, ease-of setup and use make lasers an ideal measurement method.