

# Optical Fiber Sensor: Review and Applications

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**Abstract :** Optical Fiber Sensor technology is oldest and best sensing technique. Optical fiber sensor use to measurements in different parameters like pressure, temperature, vibration, rotation etc. Most of the optical sensors are based on the Intensity, phase and wavelength. Optical Fiber Sensors offer wide advantages over the sensing system, such as small in size, low cost, longer life etc. This paper presents an executive review and useful application of optical fiber sensors.

**Keywords -** Optical fiber, Sensors, Classification, Application

## I. INTRODUCTION

The optical fiber sensors based nanostructured materials has large range of applications. Laser light was invented in the year 1960 and after the invention of lasers, researchers are shown interest in the applications of optical fiber sensor. Last few decades optical fiber sensors play very important role in the field of sensing technologies. Recent times many applications have been developed for detection of different parameters in different areas <sup>[1, 2]</sup>.

The Optical Fiber Sensors also known as Fiber Optic Sensors, which is use for sensing by optical fiber or sensing element in the different areas like medical, pharmaceutical, environmental, defence, bioprocessing and food industries. By utilizing optical fibers as transduction elements, fiber-optic physical, chemical, and biosensors is at the top of in the past decades. With the rapid development of nanotechnology, as well as the increasing demands on miniaturized sensors with higher performances, fiber optical sensors with small size, high selectivity, fast response, high sensitivity, and low detection limits are the current trends of sensing systems <sup>[1, 3]</sup>.

In those days, field of Optical Fiber Sensor has increased the use of nanocoating deposition Techniques in research area. Nanosized thin films and coatings have been applied on the Optical Fiber configurations for the fabrication of Sensors. These devices are developed for the monitoring and detection of multiple parameters such as a wide range of gases, temperature, humidity, biomolecules etc.

Optical Fiber is used as a channel to communicate with Sensors. Optical Fiber Sensors are itself efficient to monitor physical, biological and chemical changes in the object. Optical Fiber Sensors provide many advantages <sup>[3]</sup>:

- easy to execute due to their small size
- Substantial for environment
- weightless
- Advance sensitivity
- Remote sensing proficiency

## II. PRINCIPLE

The block diagram of optical fiber sensor is drawn below in fig.1. It contains optoelectronic sources like LD, LED, Photovoltaic Cell etc. In this first of all we take a Optoelectronics Source which produce light which travel through Optical Fiber after that light pass through modulating element which is measurand then light enter in detector then signal processor and finally we read the signal data which send by the source.

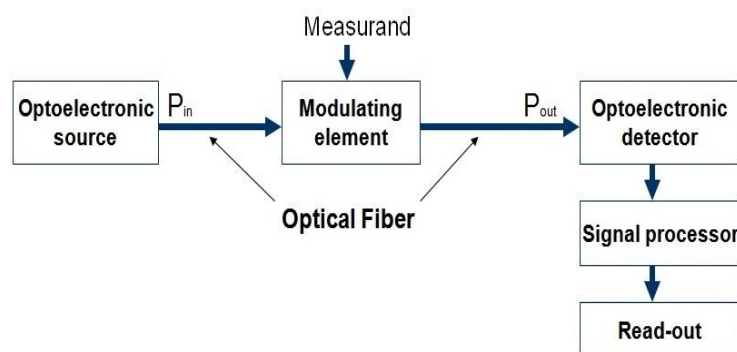


Fig.1 Generic Block Diagram of Optical Fiber Sensor System

Optoelectronic source is use to generate the light and passing through the optical fiber. The optical fiber consists of the core and cladding, which have different refractive index. The light beam travels through the core by repeatedly bouncing off the wall of the cladding and reflected back in the same medium itself and travel in the same medium as shown in fig.2. The light beam, having passed throughout the fiber without any loss in light, is diffuse at an angle of approximately  $60^\circ$  and emitted to the goal. These all process are known as Total Internal Reflection <sup>[1, 3, 4, 5]</sup>.

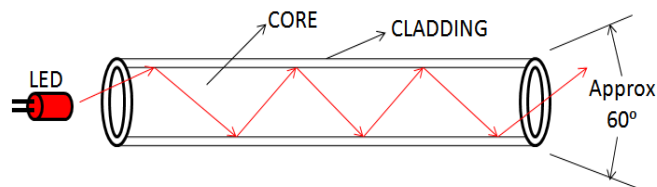


Fig.2 Light bounces off the walls of optical fiber cable

The cores are divided into following types.

### 2.1 Plastic Type

The core of the plastic fiber consists of one or more acrylic-resin fibers 0.25 to 1 mm in diameter. Plastic fibers are light, effective cost and flexible. They are most common type of fiber sensor.

### 2.2 Glass Type

The glass fiber consists of 10 to 100 $\mu$ m in diameter. Glass fibers are encased in stainless steel tubing. It is used to be at high temperatures (350°C max.).

## III. Classification

Optical Fiber Sensor can be classified in following modes:

### 3.1 Location Based

#### 3.1.1 Intrinsic

Concept of intrinsic optical sensing drawn below in fig.3, in this internal environmental feature of optical fiber change into a light signal modulation. This light signals are in form of intensity, phase, frequency and polarization<sup>[3]</sup>.

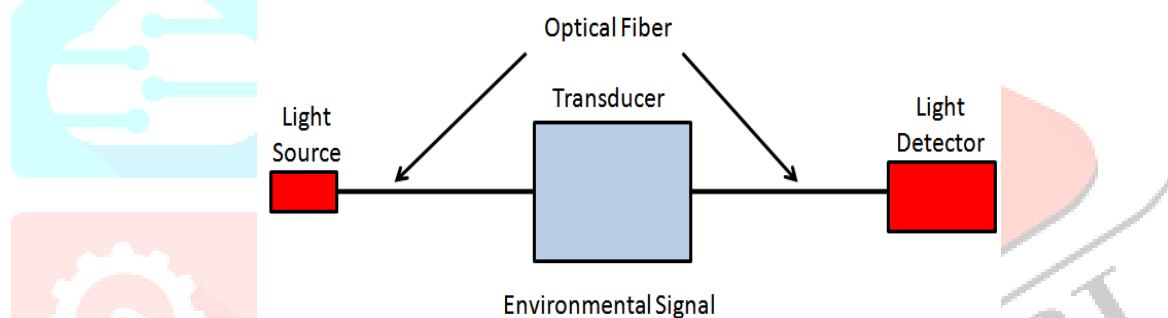


Fig.3 Intrinsic type optical fiber sensor

#### 3.1.2 Extrinsic

In this sensing, the optical fiber used as data carrier that moves with respect to the Detector and that will transmit a light signal depending on the data appear at detector. This Detector prepared by mirrors, gas, liquid cell etc. Fig. 4 showing the primary concept of extrinsic optical fiber sensor<sup>[3, 4]</sup>.

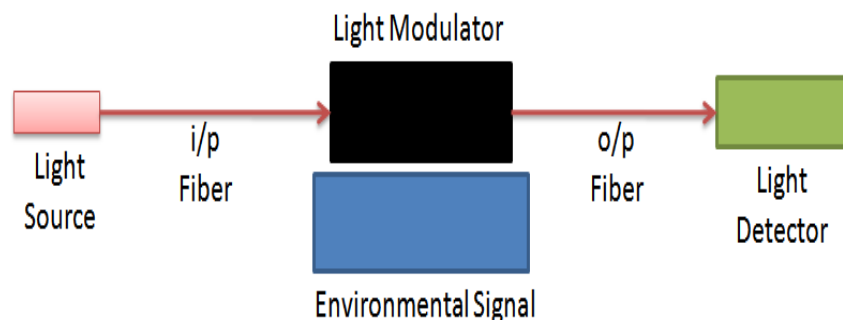


Fig.4 Extrinsic type optical fiber sensor

### 3.2 Operating Principle Based

#### 3.2.1 Intensity Based Sensor

Extrinsic types are simplest type of optical fiber sensor which is based on the intensity modulation. Fig.5 shows a simple closure or vibration sensor that consists of two optical fibers held in close proximity to each other. Light is introduced into one of the optical fibers; when it exits, the light fan out into a cone of light whose angle depends on the difference<sup>[3, 6]</sup>.

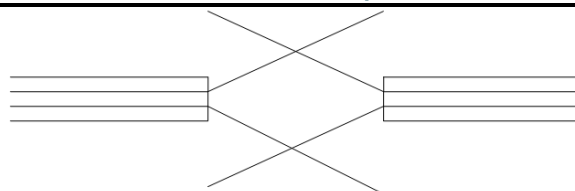


Fig.5 Closure and vibration optical fiber sensors

**3.2.2 Phase Based Sensor**

This type of sensors are used for change in emitted light in regard to change in data signal and this data signal is detect by phase modulating optical fiber sensor [3].

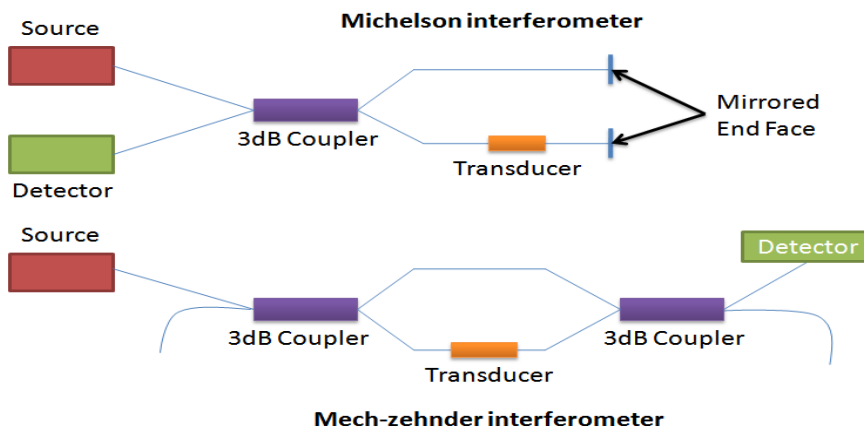


Fig.6 Michelson & Mech-zehnder interferometer

When a light beam is passed in the course of interferometer, after that the light split into two beams, one beam of them is showing to sensing environment and another beam is inaccessible from the sensing environment as shown in fig.6. When the beams are combining again and they mess consecutively [3].

The phase of the light field can also vary with the external perturbations so that the optical fiber sensor can also be built based on the light field's phase changes. The relationship between the phase change and the optical path change can be written as [6]:

$$\varphi(r, t) = 2\pi L(r,t) / \lambda$$

Where,  $\lambda$  is the wavelength of light and  $L(r, t)$  represents the change in optical path.

**3.2.3 Frequency Based Sensor**

This type of sensors are changed their wavelength. This can be driven by the light detector and that will be measured from the differ wavelength to differ measured parameter. Fluorescence sensors, black body sensors and the Bragg grating sensors are type of this [3, 7].

There used different configurations, one of them showed in fig.7. In which end tip sensor is used. When light propagates to end tip, it will answer into a light due to fluorescence and this emitted light will be detect by optical fiber and directed back to demodulator.

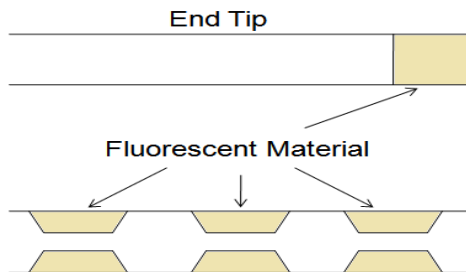


Fig.7 Fluorescent fiber optic sensor

Mostly use this type of sensor is the Bragg grating sensor. Fiber Bragg gratings are perform frame of the repeatedly changes in index refraction and the core of single mode optical fiber. This type of change in refractive index can be formed by revealing the core of optical fiber to an intense interference pattern of UV energy [7, 3].

In Bragg grating sensor operation, light emitted by LED source and centre frequency is also nearly to the Bragg wavelength. When light propagate through the Grating and sample of signal is reflected back to the Bragg wavelength [7].

### 3.2.4 Polarization Based Sensor

The direction of electric field, section of the light field is defined as the polarization of light field. Not similar type of polarization of the light field is linear, elliptical, and circular polarization. For the linear polarization, the direction of the electric field is kept in the similar line during the light propagation all the time. In favour of elliptical polarization, the direction of the electric field is change during the light propagation. The end of the electric field vector forms an elliptical shape; hence, it is called “elliptical polarized light” [3, 5].

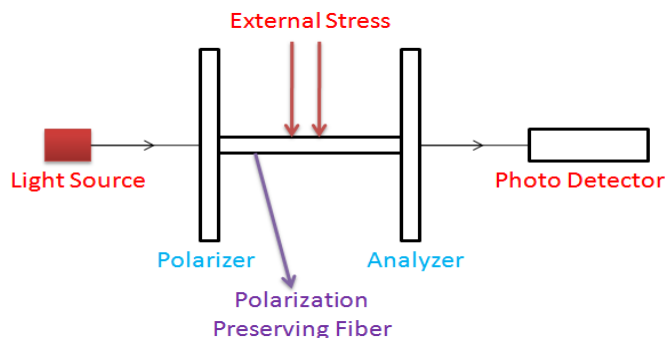


Fig.8 Polarization based sensor

Fig.8 shows the optical setup for the polarization based on optical fiber sensor. This is formed when light polarized from the light source through the polarizer. The polarized light is launched at  $45^\circ$  to the ideal axis of a length of bi-refrigent polarization-preserving fiber. This part of the fiber is served as sensing fiber. Under exterior perturbation such as tension or hassle, the phase difference among two polarization states is distorted. Then, the output polarization state is varying according to the perturbation. Hence, by analyzing the output polarization state at the end of the fiber, the exterior perturbation can be detected [5, 8].

### 3.3 Application Based

#### 3.3.1 Physical Sensor

The nature of physical phenomena includes mechanical, thermal, electrical, magnetic, atomic and nuclear, each having the properties of bodies or physical systems. These natural properties based on some physical effects on part of the fundamental of physical sensors for measuring physical quantities and converting them into signals which can be read by an observer or instrument. For example, a thermocouple converts temperature to an output voltage which can be read by a voltmeter [9].

Physical sensors have been widely used in the biomedical field. The commonly used sensors include resistance sensors, inductive sensors, capacitive sensors, photoelectric sensors and thermoelectric sensors [9].

#### 3.3.2 Chemical Sensor

Chemical sensor is defined as the device that measure aspect, quantity of a given analytic as shown in fig. 9. The complexity of a chemical sensor's application is related to the technical difficulties associated with these determinations and with the specific nature (i.e. molecule) of the chemical substance to be analyzed [10, 11].

The sensitivity of chemical sensing is affected by the phase, dimensional, and recognizable aspects of the preferred fortitude. The analyte can be present in a gas, liquid or solid phase on various ranging from bulk volume of liters to surface layers from nanoscopic to monomolecular range. It may also be repeated or transitory [10, 11].

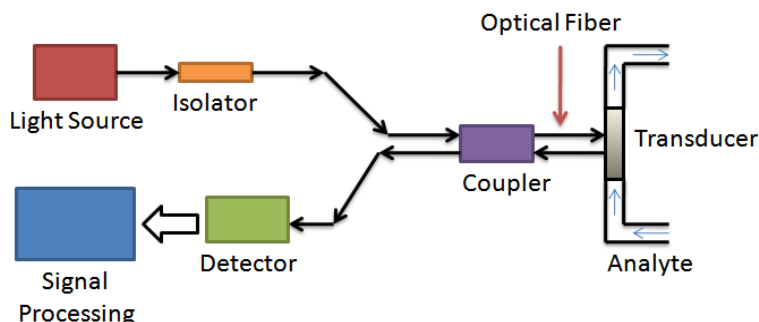


Fig.9 Chemical Sensor

#### 3.3.3 Bio-medical Sensor

A bio-medical sensor is a device which consists of a biologically or biophysically derived sensing element integrated with a physical transducer that performs a measure and into an output signal [12].

The principle of operation of a biomedical sensor can be leave by following its sensing path. A measure and is introduced to a biomedical sensor using sample delivery system. After that measure and passes through the pre-processing section, which perform initial selective screening of possible interfering factors. Then the measure and is find out to the sensing element, a biologically active material which is discerning to the measure of interest (i.e. DNA, antibodies). When a measure and interacts with the sensing element, physical, chemical and biochemical changes are produced and these changes are converted by physical transducer into output electric signal. All these functional design elements can be enclosed in the sensor package

#### IV. APPLICATIONS

Optical fiber sensors are used in several areas:

- Night Vision Camera: ability to see in low light condition, commonly used in military.
- Biometric: generally used for detection of finger prints, faces and eyes.
- Building and Bridges: in this use for monitoring the concrete during setting, crack detection, damage evaluation etc.
- Tunnels: in this use for convergence monitoring, joints monitoring, damage detection etc.
- Dams: use for joint expansion monitoring, spatial displacement measurement, leakage detection, circulated temperature monitoring.

#### V. CONCLUSION

There are certain advantages of optical fiber sensors, which are; weightless, small in size, Easy to appear, low intensity, low interference, high sensitivity, broad bandwidth and environmental strictness create them widely used in different fields. All these characteristics create it best and optical fibers are very beneficial in industries for long time investment.

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