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A comprehensive Survey of Optical Fiber Sensor: Review and Applications

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Abstract- **Recent advancement in fiber optics (FOs) and the numerous benefits of light energy over electronic systems (include resistibility to electromagnetic interference, small size, lightweight large bandwidth and easiness in implementing distributed sensors) have enhanced the application and requirement for optical sensors in various production, defense and social fields. Surroundings and atmospheric monitoring, space sciences, industrial chemical processing and biotechnology, law enforcement, digital imaging, scanning, and printing are exemplars of them. The uniqueness of photon technology could impel down prices which reduces the price of optical fibers and lasers. Fiber optic sensors (FOSs) offer a wide spectrum of advantages over traditional sensing systems, such as small size and longer lifetime. Immunity to electromagnetic interference, amenability to multiplexing, and high sensitivity make FOs the sensor technology of choice in several fields, including the healthcare and aerospace sectors. FOSs show reliable and rigid sensing tasks over conventional electrical and electronic sensors. Today, some success has been found in the commercialization of optical fiber sensors. However, in various fields they still suffer from competition with other mature sensor technologies. However, new ideas are being continuously developed and tested not only for the traditional measurands but also for new applications. This paper presents an executive review of optical fiber sensors and the most beneficial applications.**

***Index Terms*- Solar Energy, PV panel, radiation.**

1. INTRODUCTION

optical fiber sensors initiated. Various notions have been suggested and various technologies have been developed for various measurands and applications. Till date, various types of optical fiber sensors have been commercialized, but it is also true that, among the various technologies that have been investigated, only a few number of techniques has been commercially successful. Optical fiber sensors have advantages such as immunity to electromagnetic interference (EMI), lightweight, small size, high sensitivity, large bandwidth, and ease in signal light transmission. However, in many fields of application, optical fiber sensors should compete with other rather mature technologies such as electronic measurements. To appeal to users already accustomed to other mature technologies, the superiority of optical fiber sensors over other techniques needs to be clearly demonstrated. Typical users are not interested in specific techniques involved in measurement. They simply desire sensor systems having good performances with reasonable price except for very special uses. Hence, optical fiber sensor systems should be available in the form of complete systems including detecting and signal-processing electronics. In some cases such as electric protection relaying systems, the sensor systems are simply subsystems of rather larger systems. In some cases such as optical gyroscopes and optical current sensors, the optical fiber sensors should compete with other optical bulk sensors as well. Even with these difficulties, considerable efforts have been made to study of optical fiber sensors, and some of them are now nearing maturity.

Fiber optic sensor technology has often been driven by the development and subsequent mass production of components to support these industries. The inherent advantages of fiber optic sensors which include their ability to be lightweight, of very small size, passive, low attenuation, and low power, immunity to electromagnetic interference (EMI), high sensitivity, wide bandwidth and environmental ruggedness were heavily used to offset their major disadvantages of high cost and unfamiliarity to the end user[4][5].

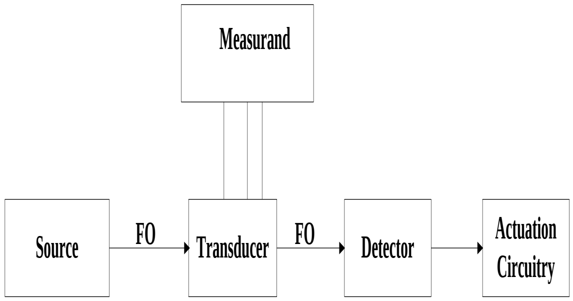

Figure 1: Optical fiber sensor system basic components

2. OPTICAL FIBRE SENSOR OVER TRADITIONAL SENSOR

The advancement in research and development of optical fiber sensor based devices has expanded their relevance to various technology fields, for example chemical, medical and telecommunications industries. Optical fiber sensors have been developed to work on a wide ranges of physical properties, like temperature, chemical changes, electric and vibrations, magnetic fields, strain, displacement (position), flow, rotation, pressure, radiation, liquid level, light intensity, and colour. For performance in adverse conditions, FOS proves dependable and rigid sensing devices over traditional electrical and electronic sensors where they find difficulties in operation [1][6][7]. In Contrast, optical fiber sensors show a number of significant advantages over other types of sensors; they are;

(1) Facilitate small sensor sizes.
(2) Are non-electrical devices.
(3) Most of the time it does not require contact.
(4) Resistant to electromagnetic interference (EMI) and radio frequency interference (RFI).
(5) Do not pollute their surroundings and are not subject to corrosion.
(6) Provide high resolution, sensitivity and dynamic range.
(7) Require smaller cable sizes and weights.

3. OPTICAL FIBRE SENSOR TYPES

Fiber optical sensors are sensors that can work in adverse conditions where traditional electronic and electrical sensors find difficulties in operation. They can sense numerous physical properties, for instance pressure, strain, position, chemical changes, magnetic and electric fields, flow, light level, vibration, colour and radiation [3][6][9].

(1) Chemical sensors; groundwater and soil contamination, remote spectroscopy.
(2) Temperature sensors; leading commercially accessible sensors, range from -40 degree Celsius to 1000 degree Celsius.
(3) Strain sensors; fiber Bragg gratings technology, senses as less as nine micro strain.
(4) Biomedical sensors; spectroscopic biomedical sensors, PH, CO_2 and O_2 can be measured at the same time, flow supervision by laser dopplerimetry.
(5) Electrical and magnetic sensors; appealing intrinsic dielectric characteristics, less susceptible to electromagnetic interference, safer, small size and they are almost all the time hybrid in nature.
(6) Rotation sensor; based on the sagnac effect, two types ring laser gyroscope (RLG) and fiber optic gyroscope (FOG).
(7) Pressure sensors; based on piezoresistive technique or movable diaphragm, high performance (polarization based sensors); operating pressure ranges from 0-70,000 torr.
(8) Displacement and position sensors; one of the first optoelectronic sensors developed, uncomplicated sensors depend on the changes in retro reflectance due to a proximal reflecting surface, also called as liquid level sensors.

4. OPTICAL FIBRE SENSOR APPLICATIONS

For adverse environmental circumstances and sensing very long distances, optical sensing is regarded as the perfect technological solution for applications where traditional electrical sensors such as thermocouples foil strain gages and vibrating wires have been proven ineffective or find difficulties in those harsh conditions. The attributes and advantages of fiber Bragg grating (FBG) optical sensing include the electrically passive, nonconductive and resistant to electromagnetic interference (EMI), sensor measurements over very long distances (10+ km), induced noise, daisy chain multiple sensors on a single fiber. Large sized and lightweight structures can benefit from the distributed single fiber architecture to simplify installation and reduce weight [10]. The nonconductive and noncorrosive nature of the fiber benefits outdoor and industrial applications where hazardous gases and voltages might be present. Also, the immunity to EMI removes the need for expensive and often difficult signal conditioning required for measurements near noisy sources such as power transformers. FBG optical sensing can benefit many applications in areas such as energy, civil infrastructure, and transportation monitoring [6] [10].

Medical field; Optical-chemical and biochemical sensing is being researched comprehensively throughout the world, and these optical sensors are finding a large number of applications in environmental monitoring, industry, biomedicine, medicine and chemical analysis [2]. The major physical phenomena exploited for optical chemical sensing are fluorescence and absorption, even though Raman scattering, chemical luminescence and Plasmon resonance have also been utilized. Health-care is indisputably the field having the most potential for future development [11][12]. Optical biosensors are finding ever-varieties of applications in various branches of medicine for several significant reasons.

Energy field; FBG optical sensing has unique attributes that make it suitable for traditionally difficult applications. Monitoring structures that generate, produce, distribute, and convert electrical power introduces many challenges that can be addressed with FBG optical sensing. Whether it is a windmill requiring a lightweight solution or a hydroelectric turbine needing an EMI-resistant system, optical sensing has unique feature that match perfectly with these traditionally difficult applications. Partial discharge detection uses optical fiber sensors optical fiber sensors are being tested for use in detecting partial discharges in electrical transformers. Pinpointing such discharges is essential to preventing insulation breakdown and catastrophic failures. For example, monitoring the structural integrity of a wind turbine blade with electrical sensors would often result in noisy measurements because of long copper lead wires. With optical sensing, accurate and noise-free strain measurements on wind turbine blades are possible with little added weight to the structure. Additionally, the distributed and non conductive nature of optical fibers lend well for numerous uses in gas and oil applications, including downhole monitoring and pipeline monitoring. Applications of energy FOS devices are wind turbine blade monitoring, pipeline monitoring, power line monitoring, offshore platform monitoring and downhole monitoring.

Civil field: Structural health monitoring systems based on traditional sensors frequently face major environmental challenges. An electrical monitoring system would require the a lightning grounding system, installation of countless wires periodic external calibration, and the potential maintenance of corroded and/or degrading sensors. With an optical sensing solution, these downfalls are all eliminated. The ability to daisy chain multiple sensors on a single fiber greatly reduces the weight and complexity of the system. Furthermore, optical fiber does not corrode or conduct like copper wire, which increases longevity and reduces the risk of damage due to lightning. These attributes, coupled with the fact that optical sensors and NI interrogators do not require calibration, drastically reduce the amount of maintenance required. Applications of civil FOS devices are large building monitoring, bridge and road monitoring, airport landing strip load monitoring and dam monitoring.

Transportation field; To guarantee passenger safety, monitoring systems are increasingly deployed to make sure the appropriate operation of, railways, airplanes ships, and more. However size, weight and unkind environmental requirements can pretense major challenges in deploying an electrical monitoring system. FBG optical sensors ease these challenges by providing lightweight distributed sensor measurements that are immune to high voltage, corrosion and EMI-induced noise. In addition, because of the long life and ease of setting up FBG optical sensors and lack of requirement for external calibration, these sensing schemes can be deployed reliably for several decades without need for any maintenance; this is exclusively beneficial for long run railway and ship monitoring. The capability to have multiple sensors on a single, very thin fiber dramatically reduces the weight of the monitoring system, which is particularly significant in aerospace applications. Applications of transportation optical devices are fuel tank monitoring, railway monitoring, Ship hull monitoring and airplane wing monitoring.

5. CONCLUSIONS

In recent times, the advancement of technology and applications based on fiber optics has been evolved very rapidly. As a corporal medium, optical fiber is subjected to various perturbation of at all times. Thus, it has experienced change in size and shape. Optical (refractive index, mode conversion) changes to a larger or lesser extent depending upon the nature and the magnitude of the perturbation. It is critical for communication based application to be dependable all times and to curtail various impacts on transmitted signals. Alternatively, in the area of fiber optic sensing, the answer to external impacts is purposefully enhanced so that the consequential change in optical radiance can be used as a measure of the exterior perturbation. Since light energy is distinguished by amplitude (intensity), frequency, phase and polarization, any one or more of these strictures may undergo significant changes. The fiber behaves as a modulator in sensing phase, whereas in communication, the optical signal passing through an optical fiber is already modulated. It also works as a transducer that converts measurands into a corresponding change in the optical radiation. Optical fiber sensor offer many significant advantages such as wide bandwidth, liberty from EMI, compactness, arithmetical versatility and economy. Certainly of passive, dielectric construction and high sensitivity when compared to several other types of sensors. Exclusively manufactured fibers can withstand Very high temperature and other adverse environments. In remote sensing and telemetry applications, it is possible to use a section of the optical fiber as a sensor gauge while a greater length of the same or another optical fiber can communicate the sensed information to a remote area station. Utilization of array and distributed sensor covering extensive structures and geographical locations is also possible.

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