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# AN INVESTIGATION OF THE TYPES AND APPLICATIONS OF FIBER OPTIC SENSORS

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## Abstract:

Optical measurement techniques like as spectrometry, interferometry, and polarimetry have long been used in materials measurement and environmental assessment. The optical fiber increases the flexibility of applying these basic concepts. Fiber-optic technology has made major strides in measurement science over the past thirty years. This study's perspective on these contributions, while not exhaustive, highlights the conceptual advances achieved in the early days of optical fiber technology and the variety of uses that have emerged. There is a clear future for more in-depth research when guided-wave optics is applied to fresh and challenging measurement requirements like cellular biology, art restoration, and microsystems characterization.

***Keywords: Intrinsic Sensor, Intensity modulated Sensor, Multiplexing System ,Fiber Optics Sensors, Extrinsic Sensor,***

## INTRODUCTION

Fibre optics has unquestionably had a big impact on the communications industry [1]. The recognition in the early to mid-1960s that optical signals might be transmitted over glass or silica fibers with a loss that might be less than that of coaxial copper cables can be traced back to the seminal papers of Kao and Hockham, Simon and Spitz, and others [2, 3]. Moreover, unlike copper, which increases loss with baseband modulation frequency, the loss in optical fibers could be maintained for every feasible modulation frequency. Zones with little dispersion were found to be present in the silica transmission characteristic by Dyott [4] some time later. Fibre optics had already existed in 1965. Glass fibres had already been used in decorative lamps, and the fundamental concepts of the electrical waveguide were well known. It had already become commonplace to use optical fibres to direct light to and from a location where a measurement was to be performed.

As reported in the literature, the first patents for fiber-optic sensing had been filed and had materialized as a test product [5].Around the same time, Eli Snitzer's ever-inventive mind suggested using fiber optics to convey phase-modulated signals [6], which laid the groundwork for another important class of fiber-optic sensors.This means that the main focus of this research will be on the development, research, and uses of fiber-optic sensor technology throughout history. The optical fibre sensor (OFS) community became influnced with communications enthusiasm over 35 years ago, and by the mid-1970s to the early 1980s, they believed that OFS technology was the answer to all of their problems. Though perhaps a little slowly, realism has percolated, and today we are aware of areas of genuine application, but there are still intriguing and important concerns that can excite the research community.

## SENSING APPLICATIONS

Measurement and sensing call for a high degree of expertise. There are sensor technologies tailored to certain applications. Every sensor is used in a certain industry. Numerous physical and chemical processes form the basis of the sensing mechanisms, which are then interfaced to electrical signal conditioning through an endless number of additional specially created protocols. This leads to a highly fragmented market, which makes things tough and unsatisfactory for those who operate in it. Fiber-optic sensing is conceptually incompatible with fiber-optic communications since they share a great deal of almost identical system designs and components. It is not common to see spin-offs from the communications industry into sensor technologies. Another key generic characteristic of sensing techniques.The transduction process uses virtually all physical and chemical processes, all of which are temperature sensitive. Temperature is not a factor in the majority of measurements. Because of this, temperature changes must first be corrected for in most sensing and measurement systems. This is a persistent problem that has undoubtedly influenced fiber-optic sensor technology, leading to approaches and solutions with varied degrees of elegance and ingenuity.

## TECHNIQUES OF FIBER SENSING

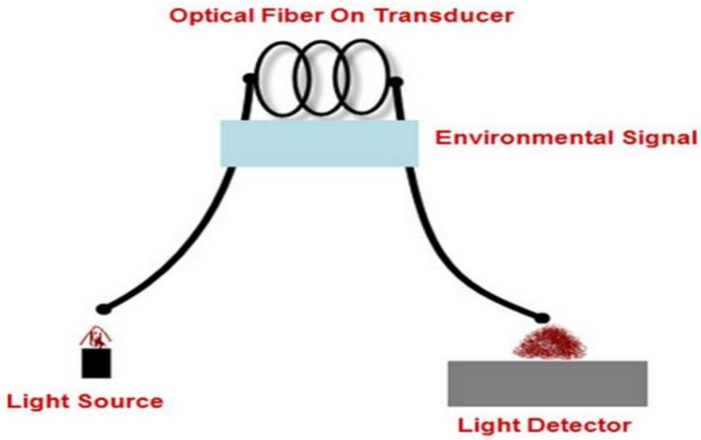

Figure 1: Intrinsic Type Fiber Optic Sensors [7]

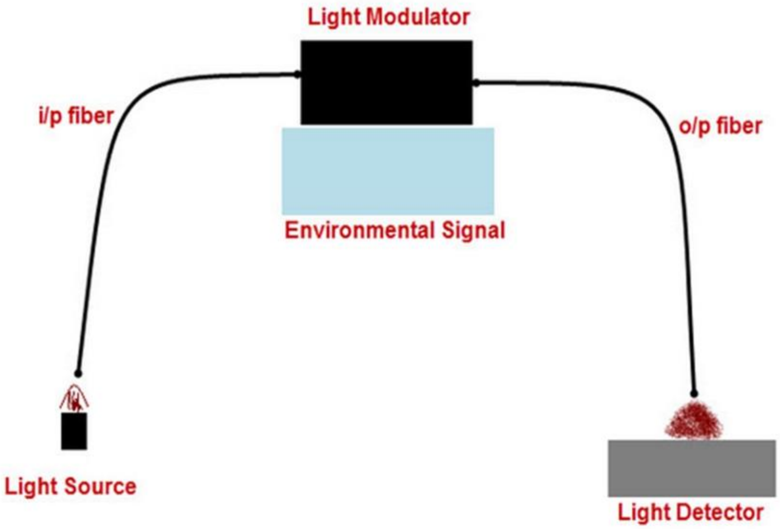

Figure 2: Extrinsic Type Fiber Optic Sensors [7]

Figure 1 and Figure 2 presents a diagrammatic illustration of the fibre sensor. Simple fundamental elements are used. Using an optical fibre, light is transported to a modulation region where it is modified by a physical, chemical, or biological phenomenon. The modulated light is then carried back to a receiver where it is detected and demodulated. Ideally, the demodulated signal and the phenomenon of interest have a one-to-one correspondence . The first step is to guarantee that the parameter to be measured and the demodulated signal have a one-to-one relationship; the second is to match the technology to the application in terms of both performance and cost. Although the impact of the fibres to and from the modulation region, variations in source and detector characteristics with temperature and time, and the impact of temperature on the modulation process are all significant, the first of important problems these is the simpler one. The second of these must acknowledge the existence of established methodologies and, in particular, must identify otherwise unsolvable issues that are crucial but have not been adequately addressed due to technical issues.

Intrinsic Type Fiber Optic Sensors, sensing takes place within the fiber itself. The ability of the sensors to translate an environmental action into a change of the light beam flowing through them depends on the characteristics of the optical fibre itself. In this case, the frequency, phase, polarisation, or intensity of the light signal might be considered one of its physical qualities. The intrinsic fibre optic sensor's ability to deliver distributed sensing across great distances is its most advantageous characteristics. In fibre optic sensors of the extrinsic type, the fibre may serve as a means of transporting information to a black box.

Depending on the information received at the receiver, it produces a light signal. Rotation, vibration velocity, displacement, twisting, torque, and acceleration are all measured with these sensors. The capacity of these sensors to access locations that would otherwise be inaccessible is their main advantage. [7]

## INTENSITY MODULATED SENSOR

Specifically, for high numerical aperture fibers that receive uniform light from an incandescent bulb—for which the sensor was initially designed—the fraction of light transmitted between the bundle's transmit and receive elements depends on the distance between the reflector and the bundle, and it is, approximately speaking, unaffected by the target object's small rotational angles. Naturally, variations in the target's reflectivity will result in a change in the transmission ratio. Nonetheless, the creators had foreseen this scenario and developed compensatory schemes to address the problem. These required the employment of two receiving bundles, each placed a certain distance apart. Therefore, the distance between the bundle's end and the target determines how much light is received in each of these receiving bundles. As a proximity measurement system, the Fotonic sensor has shown some limited success in real applications. It possessed micrometer-level resolution, does not physically touch the target, and had all the standard optical benefits in terms of electromagnetic interference.

This essential sensor has since undergone numerous configuration revisions. The idea of fiber bundles has been replaced by individual fibers, and the light source's intensity has been increased by light-emitting diodes and super radiant systems. There have been slight modifications made to the intensity fluctuation compensation plan. On rare occasions, it has been used to establish separate transmit and receive fiber locations. The context of the application has changed. The concept has been demonstrated for measuring angular rotation instead of longitudinal displacement, checking gas turbine engine blade clearances, monitoring machine tool wear and monitoring the displacement of pressure diaphragms in pressure sensors for automotive and medical applications.There are several of optical fibre sensor technology is demonstrated by the Fotonic sensor. It took 35 years to develop and present. It has frequently undergone reinvention. On rare occasions, it has been employed seriously in applications that were unimaginable when the concept was first proposed. It employs straightforward intensity modulation and has the capacity to reference, if necessary, to eliminate the effects of variations in reflectivity, fibre loss, and source output. Finally, rather than being a property of the optical system itself, temperature sensitivity is a property of the mechanics of the reflector mounting and movement.

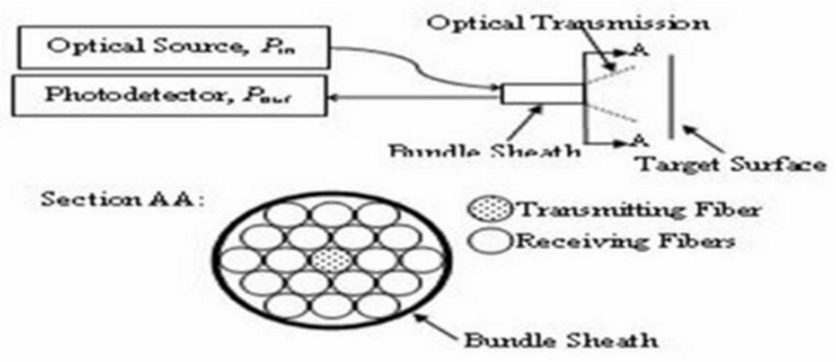

Figure 3: Example of Intensity Modulated fiber optics sensor. [8]

## DISTRIBUTED SENSOR

The interferometer measures the variation in path length from end to end along the fiber that is arranged to interact with the physical parameter field. Light can interact with its surroundings in a variety of ways, some of which can be configured to enable the creation of a probe that reveals a parameter field as a function of position along the fiber length. The technique referred to as "distributed sensing" is unique to fiber-optic technologies. A time-domain reflect meter can be used to read very few electrical cables, but none have the robustness, adaptability, and precision of the fiber-optic model. In order to expose typically a temperature or strain field, distributed sensing relies on backscatter and on modulating the backscattered radiation produced by an optical beam travelling forward. There have been three main backscattering techniques used.

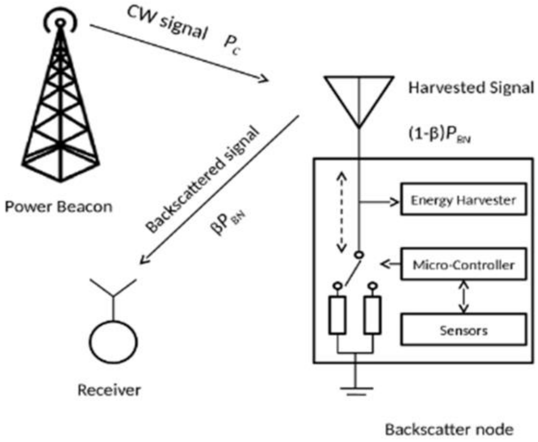

Figure 4: Generic distributed sensing concept using elastically (linear) orinelastically (nonlinear) backscattered light as theinformation carrier [9]

Rayleigh backscatter produces the strongest signal of the three, but the intensity that is reflected back is simply a reflection of the intensity that was initially present at the scattering spot. Therefore, Rayleigh backscattering devices need to use a secondary method to adjust this intensity. The acoustic phonon spectrum of the fiber is closely related to an offset frequency spectrum resulting from brillouin scatter. A measurement of the offset spectrum effectively generates a frequency that is dependent on the acoustic velocity in the optical fibre and the wavelength of the illumination source, which can then be stimulated by the illuminating optical beam. Considering that the former results from the latter, which in turn depends on temperature and strain. Ramanscatter measures the temperature at the scattering site by probing the optical phonon spectrum, for a thorough explanation of these interaction mechanisms, [10], [11]–[13].

The fundamental concept of distributed sensing was understood in the late 1970s [12], and the Raman distributed temperature probe was quickly mentioned [13]. A decade later [14], when the first Raman temperature probes were starting to appear commercially, the potential of Brillouin became significant. One of the most effective instruments provided by fiber-optic sensor technology is distributed sensing. It makes it possible to take special measures that are not possible with competing technologies. However, a complicated specialised and hence expensive piece of equipment, an optical time domain reflectometer (OTDR) designed to detect time variable Brillouin or Raman spectra, distributed sensing has found its niches despite this very important characteristics.

### ***Multiplexing Systems***

With the extremely small bandwidths required by sensing applications, optical systems have very good signal-to-noise ratio potential at the typical power levels involved in optical fibre transmission. Additionally, the signal-to-noise ratio only drops as the square root of power if the receiver power is below the shot noise limit. These straightforward discoveries led to the idea of multiplexing sensor arrays, which has been around for quite some time [15], and the concept of distributing this power among a number of sensors. A variety of topologies based on ladders, stars, and their combinations are possible for connecting the sensors. Additionally, multiplexing plays a significant role in Bragg grating technology (see below). However, up to 128 components can be usefully configured into a single array and fed from a single optical system, even with highly lossy sensors, like gas cells [16].

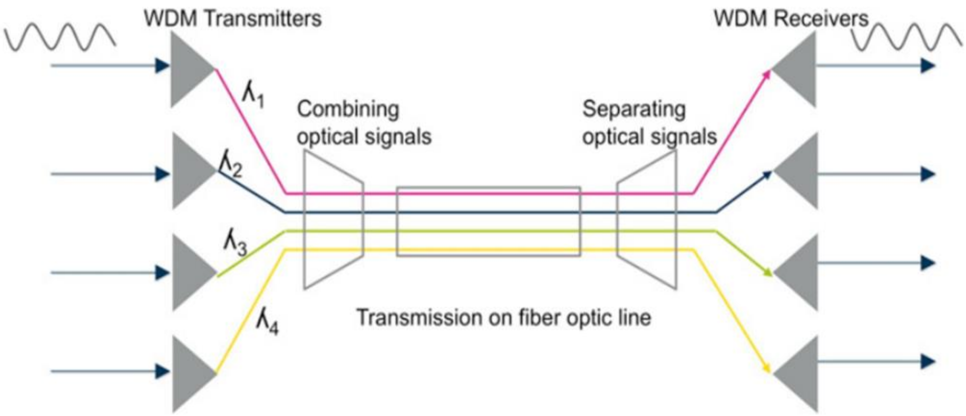

Figure 5 : WDM by multiplexing a variety of optical carrier signals onto a single optical fiber by using different wavelengths. [16]

### *Fiber Bragg Garting (FBG)*

Midway during the same incredibly fruitful era, in the mid-1970s, the photorefractive effect in optical fibres was first discovered [17].Periodic structures can be created along the core of an optical fibre using the photorefractive effect, and these periodic structures (Fig. 7) serve as highly selective optical filters. The period of the grating, which in turn could be altered by temperature and phase excursions that alter the optical path length within the grating structure, determines the wavelength of reflection. Fibre Bragg gratings are a broad topic that mostly has communications-related uses for components like wavelength tuning and stabilisation structures and optical filters. A decade or so after the gratings were first created by dire cting opposing beams along the fibre, side illumination techniques utilising ultraviolet lasers gave the requisite freedom in defining the periodic structure [18].

Fibre Bragg gratings can be sequentially written down a single fibre in the context of sensors, and they can also be constructed to reflect light in several wavelength bands. As a result, a linear array of, for instance, 16 gratings can offer 16 distinct sensing points, each of which can be uniquely recognised using a spectral slicing technique. The period of each grating can then be determined by precisely measuring the wavelength in the reflected spectrum, typically using a stabilised reference. The optical route length affects this periodicity, which provides a clue as to the combined temperature and strain fields. The linear array of Bragg gratings can function as a multiplexed strain gauge array in an environment where the temperature is constant (or compensated for by other factors).But this is a unique array in certain ways. It may be attached to or implanted in a wide range of host materials, is incredibly small, and does not require distinct wires to connect to each strain measuring site. In the past ten years or more, bragg gratings have undergone substantial investigation as strain gauge components, and today they are likely the most widely discussed fibre sensor technology.

An optical fiber core refractive index is periodically modulated by an FBG. A FBG is frequently pictured as a barcode-like design with over 20,000 stripes imprinted over a fibre length of 10 millimetres.Depending on the periodicity of the grating, the periodic pattern in the fibre (i.e., FBG) reflects a certain wavelength of light. The reflected wavelength will shift if the periodicity is altered, for example, by lengthening the fibre near the FBG.Such an FBG is frequently employed in tough situations where traditional (electrical) sensors fail and is used to monitor many kinds of physical characteristics, such as temperature, pressure, and strain.

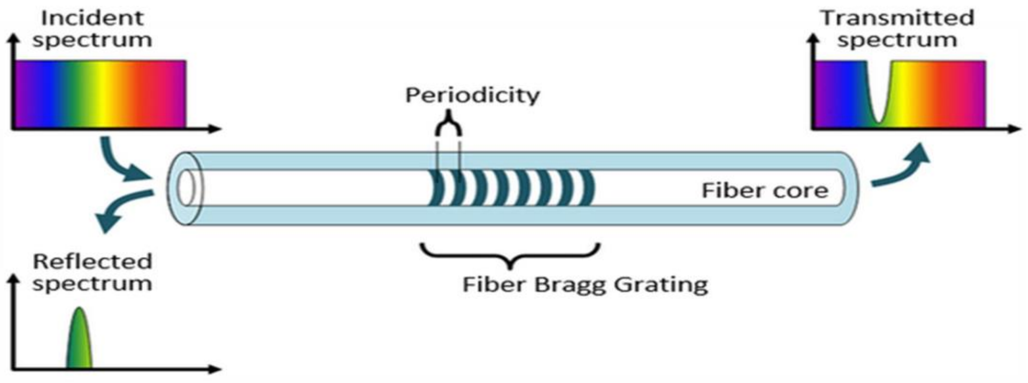

Figure 6: Schematic representation of the fiber Bragg grating (FBG) working principle. [19]

## CONCLUSIONS

One of the many applications for fiber optic sensors is the measurement of physical characteristics such as temperature, displacement, velocity, and strain in structures of any size or shape.Tracking in real time the physical characteristics of health. Buildings, bridges, tunnels, dams, and historical structures. Calculating vehicle wheel loads, utilizing electronic security systems, night vision cameras, and partial discharge detection. Applications for fiber optic sensors have been proposed thus far. Numerous advantages come with using fiber optic sensors for long-distance communication, including their small size, low weight, compact design, high sensitivity, wide bandwidth, etc. All of these characteristics allow for the highest possible use of fiber optic as a sensor.

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