A Simple Fiber Optic displacement Sensor for Measurement of Light Intensity with the Displacement

Trilochan patra

Assistant professor, Department of Electronics and Communication Engineering,
Techno India college of Technology, Newtown, Kolkata-156, West Bengal, India

Abstract - Over the last two decades, the fibre optic technology has passed through many analytical stages. Some commercially available fibre optic sensors are being used for automation in mechanical and industrial environments. They are also used for instrumentation and controls. In the present work, a fibre optic displacement sensor is presented. This type of sensor is an intrinsic sensor. In this paper our aim is to study the different results of displacement sensor using fibre optic coupler.

I. INTRODUCTION

Optical fiber can be used as a medium for telecommunication and computer networking because it is flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because light propagates through the fiber with little attenuation compared to electrical cables. Fiber optic technology offers the possibility for developing of a variety of sensors for a wide range of applications. Optical fibers can be used as sensors to measure strain, temperature, pressure and other quantities by modifying a fiber so that the property to measure modulates the intensity, phase, polarization, wavelength, or transit time of light in the fiber. Sensors that vary the intensity of light are the simplest, since only a simple source and detector are required. A particularly useful feature of such fiber optic sensors is that they can, if required, provide distributed sensing over distances of up to one meter. Fibre optic based sensors have drawn much interest due to their salient features. A number of sensing techniques based on intensity and phase modulation were investigated and a variety of sensors were developed for various parameters such as colour, gas concentration, corrosion, temperature, fluid flow, contamination, pressure, physical intrusion etc. Various researchers have reported the application of fibre optic sensors in broad areas such as: health monitoring of civil and aerospace structure, buildings leading to the concept of smart structures and synthetic skins. Such structures and skins shall have the ability to sense the environmental changes occurring within or around them by way of responding to these changes through the use of appropriate materials. This has opened up new areas of research in new materials which exhibit change in some of its properties conducing to alter the wave propagation pattern along the fibre. Fibre optic displacement sensors are commonly constructed from plastic multimode optical fibres which has low optical signal transmission loss, compact and compatibility with optical fibre technology. Three distinct methods are competent and normally used for the displacement measurement. Laser interferometer technique is based on fringe counting and has high resolution and stability of measurement. However its precision and stability are depended on the wavelength of light. Wavelength modulation needs Fibre Bragg grating (FBG) and optical spectrum analyzer for physical parameter detection and data acquisition respectively, which are very costly. A large number of fibre optic displacement sensors are based on intensity modulation of the light which is the simplest method to obtain a high resolution measurement. The intensity modulation-based sensors used the modulation of light power transmitted between the head of the sensor and the target surface. They are relatively inexpensive, non contact measurement, easy to be fabricated and suitable for employment in harsh environments.

The optical displacement sensors have many applications in different fields. They are used in medical fields, industrial fields and smart structure fields. Displacement sensor also has many general applications. They are used for measuring glass thickness, measuring door attachment offsets, measuring dimension of electronic components, detect loose sheets, detects rail distortion, detect liquid level of solder bath. In medical application displacement sensors are used for endoscopy, therapy and diagnosis. They are also used to measure accurately sealing dispenser height, assembly inspection of lenses. They are used to detect vinyl cushioning material from top of medicine bottles. In industrial field they are used to measure height prior to IC package sealing. They also detect pinholes on sealed containers and detect the position of the welding point on ring gears. Displacement sensor also counts copy machine staples and detect eccentricity, vibration of processing machine. In many civil structures like bridges, tunnels and dams the displacement sensors are useful to gain complete understanding of the structure's behaviour. If any deformation or faulty arises then we make know with the displacement sensor. In an earlier work, a displacement sensor has been demonstrated using a bundle fibre. This sensor demonstrates both front and back slopes which limits the measuring range of the displacement. **In this paper we perform an experiment by using single fibre, pair of fibre and bundle of fibre. We have also discussed their result and conclusion.**

II. EXPERIMENTAL ARRANGEMENT

Following Fiber-optic components are required for completing the experimental set-up:(i) He-Ne laser (ii) Polarizer (iii) Polarizer/Analyzer (iv) Fiber-optic coupler (5) Mirror (6) Photo detector (7) Power Meter. The connecting arrangement is shown in Fig 1, where it can be seen that the intensity of the light is changed with the displacement of mirror. The displacement of mirror is shown in the Fig 1 by dotted line. The optical signal is converted into the electrical signal by photo detector and this electrical signal is measured by power meter.

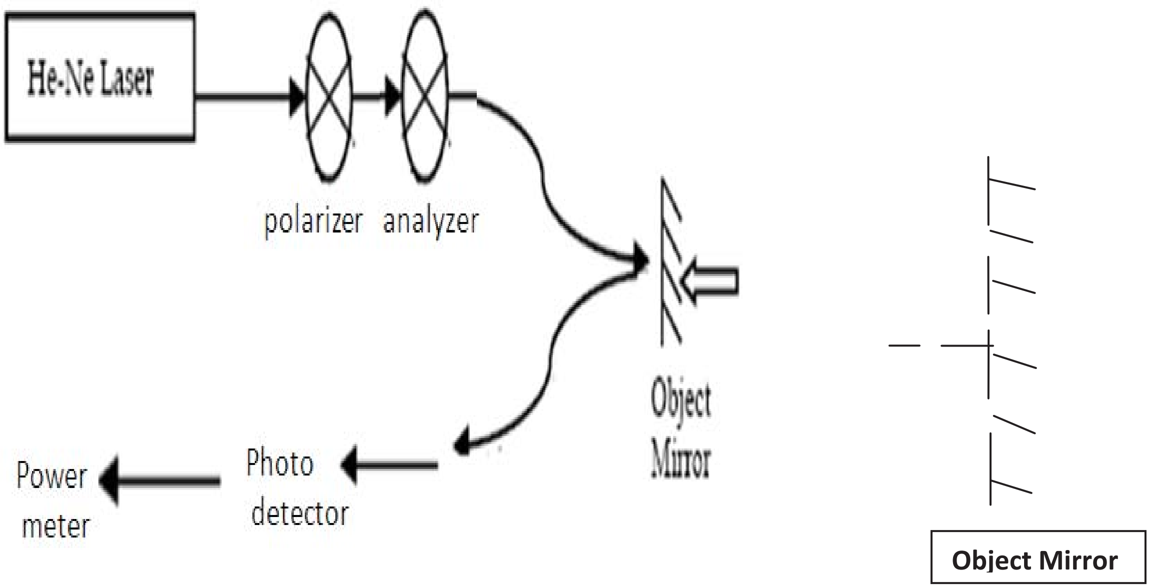

Figure 1

III. OBSERVATIONS AND RESULTS

OBSERVATIONS: The displacement of mirror is shown in 1^{st} column of table 1, table2 and table3. In table1 when we use single fiber, with the increase of displacement the light intensity decreases. In table2 when we use pair of fiber, with the increase of displacement first light intensity increases and then decreases. In table3 when we use bundle of fiber, with the increase of displacement light intensity decreases. All the reasons are explained in conclusion part.

Table 1: (When we use single fiber)

Micrometer reading (micrometer)	Power meter reading (dB)
1. 50	0.36
2. 100	0.25

3. 150	0.15
4. 200	0.10
5. 250	0.07

Table 2: (When we use pair of fiber)

Micrometer reading (micrometer)	Power meter reading (dB)
1. 50	0.45
2. 100	0.80
3. 150	1.00
4. 200	0.70
5. 250	0.50

Table 3: (When we use bundle of fiber)

Micrometer reading (micrometer)	Power meter reading (dB)
1. 50	0.40
2. 100	0.37
3. 150	0.30
4. 200	0.25
5. 250	0.20

RESULTS: All the results are shown by theoretically and experimentally. The dotted line shows the experimental result and the colored straight line shows the theoretically result. The theoretically results are based on mat lab simulation.

1. Graph for Table1: (when we use single fiber)

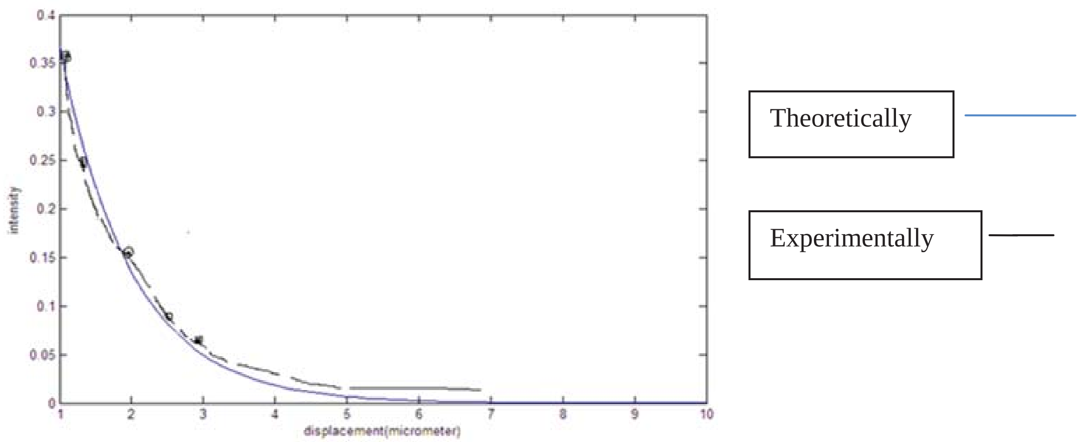

Figure 2

2. Graph for Table 2 (When we use pair of fiber)

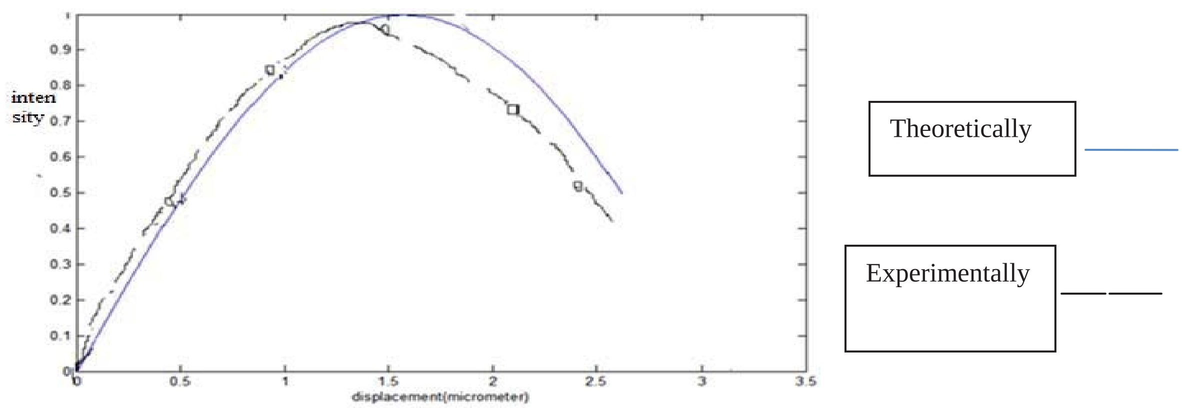

Figure 3

3. Graph for Table 3 (when we use bundle of fiber)

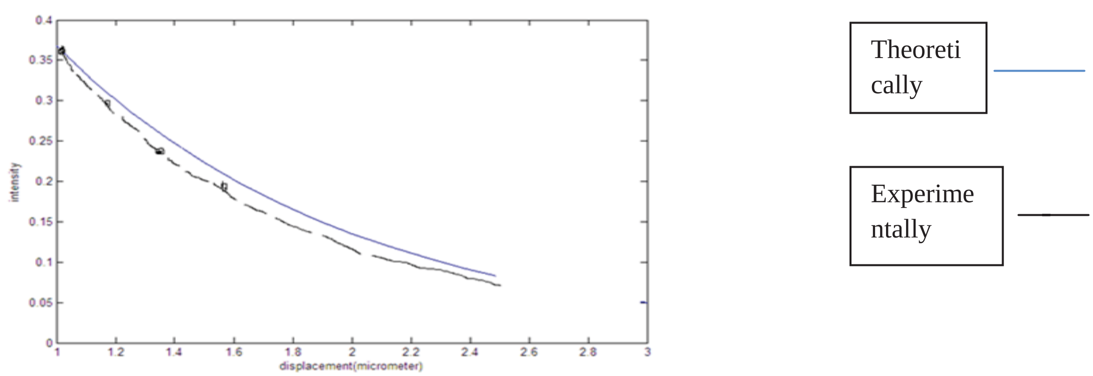

Figure 4

I V. CONCLUSION

In **Fig**.**3**, the curve exhibits a maximum with a steep linear front slope and back slope which follows an almost inverse square law relationship for the reflected light intensity versus distance of the mirror from transmitting fiber end. The signal is minimal at zero distance because the light cone does not reach the core of both receiving fibers. As the displacement increases, the size of cone of the reflected light at the plane of fiber also increases, which then starts to overlap with the receiving fiber cores leading to a small output voltage. Further increases in the displacement lead to larger overlapping which in turn results in an increase in the output voltage. However, after reaching the maximum value, the output voltage starts decreasing even though the displacement increases. This is due to the large increase in the size of the light cone and the power density decreases with the increase in the size of the cone of light.

In **Figure 2** and **Figure 4** the sensors only have one slope and the sensitivity is higher at the smaller core diameter**.** At core diameter of 0.5 mm (for both transmitting and receiving fibers), the sensitivity is obtained at around 0.0002 mV/µm, which is the highest and the slope shows a good linearity of more than 99% within a range of 900µm. The linear range increases to 3195 m with the larger core diameter of 1.0 mm. In case of the receiving core is bigger than the transmitting core, the voltage is almost constant at small axial displacements due to the coherent light source, which has a small divergence angle.

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