

Fiber optic micro-displacement sensor using coupler

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A simple technique is presented for the fiber optic displacement sensor using coupler, using multimode plastic 50:50 coupler based on intensity-modulated technique. We have measured very accurately the displacement of the order of $10\ \mu\text{m}$. The source in the IR region of wavelength 783 nm, output power of 3 mW and Laser drive of model-501 (Newport) and detector model-818-SL (Newport) are used for experimental setup. The displacement of 0-1 mm is quite interesting for the sensing. The sensor characteristics are measured at back slope. The working principle of the sensor is presented as well as experimentation results. The designed simplest sensor finds its application in industries as position control and micro displacement measurement in the hazardous region.

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1. Introduction

The fiber optic sensor is one of the most interesting and developing field. The fiber sensor are becoming day by day more attractive over other sensors, due to immune to EMI, non-electrical, high accuracy, easy to install, non-contact, explosion proof small size and weight, the fiber optic replaces other sensors. A number of varieties of parameters like temperature, humidity, pressure, pH, chemical concentration and displacement can be measured accurately.

In fiber optic displacement sensor the reflected light from mirror is coupled back into a fiber from a reflecting surface and is compared this power with a portion of power emitted by the same light source [1-2]. In fiber optics displacement sensor single mode fibers are rarely used, due to small core radius and small numerical aperture [3]. The multimode fibers are widely used in sensing because of their better launching, high core radius, high numerical aperture and receiving the maximum reflected light from the target [4]. Fiber optic displacement sensor is used in industrial metrology, packaging, signal processing and multiprocessing and hence their acceptance in diagnostic and control system [5]. An optical sensor with coupler has been developed in our laboratory. The principle, performance of the fiber and results are discussed.

2. Measurement principle and structure

Fiber optic coupler is used as tool to measure the displacement. The couplers are specially designed as optically passive media and bi-directional. During the manufacturing of 2×2 coupler, two fibers are stripped of their coatings and held together by a twist. The fibers are then fused together using a source of heat or an electrical resistive heater. The fused fibers are tapered by heating and pulling apart the two ends of the fused region. When the desired coupling ratio is achieved the heating and

pulling is stopped. The coupler is attached to a thin silica rod in order to prevent bends and strain on the fused region.

The multimode plastic 50:50 (2×2) coupler with step index fiber of diameter 1 mm, core refractive index 1.492, cladding refractive index 1.419 and numerical aperture (NA) 0.51 is used.

In displacement sensor, commonly two methods are adopted. The Phase-modulated interferometric sensor [6, 7] and intensity modulated sensor based on reflection [1, 2]. The phase-modulated sensor compares the phase of light in a sensing fiber to the reference fiber in a device known as an interferometer. Most commonly intensity modulated sensors are used in displacement sensor. The displacement causes a change in received light intensity, which is the function of displacement between fiber probe and reflecting surface. This type of displacement sensor involves two fibers (single / bundle) one for sending and other for receiving the reflected light as shown in Fig. 1.

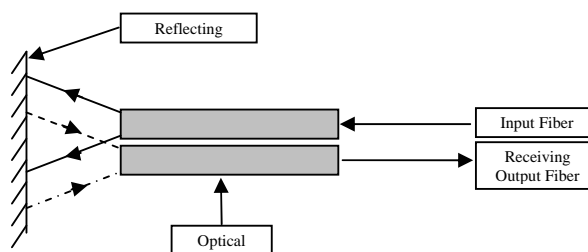


Fig. 1. Two fibers displacement sensor technique.

The intensity variation is dependent upon the distance between the reflecting surface and end of the fiber probe. The nature of the graph is shown in Fig. 2. It has both front and back slope.

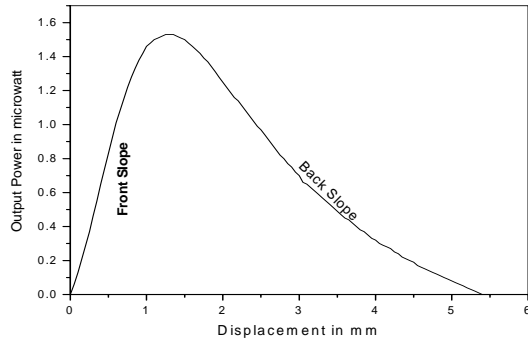


Fig. 2. Two fiber optic displacement sensor characteristics.

Our experimental micro-displacement sensor with 50:50 coupler with only one fiber is used for sending and receiving the light, which is shown in Fig. 3.

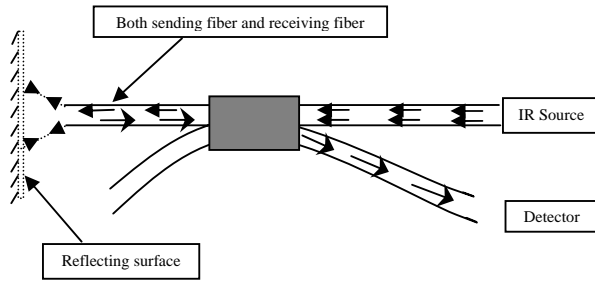


Fig. 3. Fiber optic coupler displacement sensor technique.

The distance and reflected power vary in accordance with inverse square law [8], which can be simplified as

$$\frac{p_i}{p_o} = \frac{d^2}{(2x \tan \theta)^2} \quad (1)$$

Where P_o = Output Power
 P_i = Reflected Power
 d = Core diameter
 x = Displacement
 $\theta = \sin^{-1}(NA)$ (where NA = numerical aperture)

3. Experimental setup

The experimental setup is shown in Fig. 4. Laser drive of model-501 (Newport) drives the light in IR region of wavelength 783 nm and an output power of 3 mW. The light is launched into the one end of the fiber coupler. The mirror is mounted on a fine-tuned micrometer translational stage, where the distance between the output fiber tip and the mirror can be varied in the successive steps of 10 μm .

The detector model 818-SL (Newport) is used as detector that measures the light reflected from the mirror. The detector is connected to a power meter model 1815-C (Newport), which measures power in terms of μW . The power is measured against the corresponding change in micrometer translational stage.

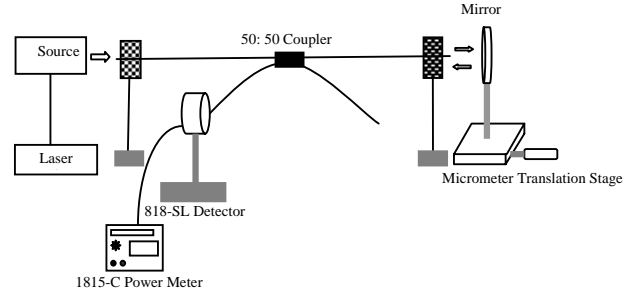


Fig. 4. Experimental setup for fiber optic displacement sensor using 50:50 coupler.

4. Results and discussion

In our fiber optic coupler sensor the front slope disappears, only the back slope exists. The transmitting and receiving of light takes through the same fiber of the coupler. The relationship between the micrometer displacement and output fiber power for IR source is shown in Fig. 5. The graph shows a very good linearity in the range of 0-1 mm. The graph exhibits the non-linear properties above 1 mm displacement. In case of two-fiber displacement sensors, both the front and back slopes arise. The front slope is highly sensitive and useful for close distance target. The back slope is less sensitive and useful for long distance. In our displacement sensor, the back slope is very sensitive for close distance target and can measure displacement directly. The displacement is measured accurately in the steps of 10 μm .

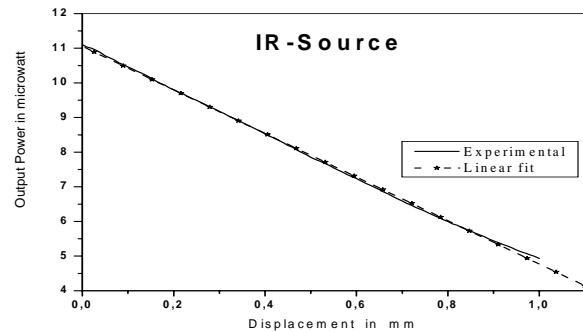


Fig. 5. Output power reading in μW as function of displacement in mm.

The performancere of the sensor is given in Table 1. We get the displacement range upto 2 mm. In the range of

0-1 mm shows a very good linearity and of standard deviation 0.051. The sensitivity of the sensor is $6.28 \mu\text{W} / \text{mm}$. With these performances, the sensor is very active in the small displacement.

Table 1. Performance of the displacement sensor.

Parameter	IR Source
Displacement range	2 mm
Linearity range	1 mm
Resolution	$10 \mu\text{m}$
Standard deviation from linearity	0.051
Sensitivity	$6.28 \mu\text{W} / \text{mm}$

The experimental results obtained are in close agreement with theoretical values as calculated using equation no. 1 and are shown in Fig. 6.

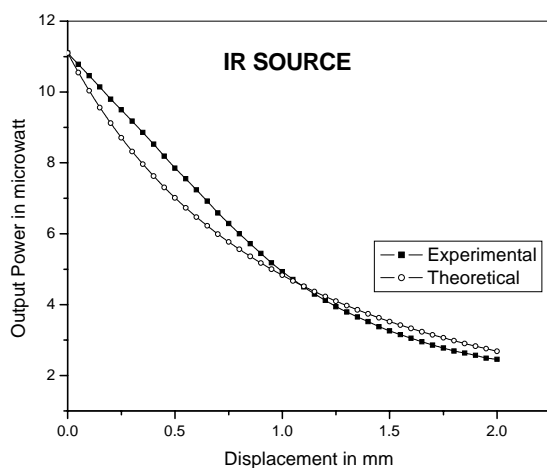


Fig. 6. Comparison between the experimental and theoretical values.

5. Conclusion

Based on intensity modulation a simple and effective fiber optic micro-displacement sensor technique is presented. The results are linear for IR light of wavelength 783 nm. Due to the simplest and compact design of such type of sensors, they find applications in industries as monitoring automated control, position control and micro-displacement measurements in the hazardous regions. Such type of micro-displacement sensor has relatively small measurable displacement range, but very sensitive over a small range.

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