Effect of offset between transmitting and receiving Fiber tips on dual-fiber displacement sensing

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The effect of offset (length difference) in two- fiber displacement sensor is presented in this paper. The performance metrics such as, blind region, peak voltage, linear operating region and sensitivity were studied experimentally for three configurations, Equal fiber(EF), Shorter Transmitter(ST) and Shorter Receiver(SR). The results show, the sensitivity of ST decreases and the sensitivity of SR increases with increase in the offset between the fibers. The operating linear region and peak voltage are shifted to shorter distance and the blind region is decreased with increasing the offset in both SR and ST configurations. The SR probe shows less dead region in comparison with the EF and ST. The bandwidth (FWHM) is unaffected due to offset in both ST and SR configurations and it is equal to EF.

(Received May 26, 2011; accepted July 25, 2011)

Keywords: Displacement sensor, Equal fiber, Shorter transmitter, Shorter receiver, Offset

1. Introduction

Fiber optic sensors are becoming more important due to their applications in various fields. One of the applications of the sensor is in high-precision non-contact displacement measurement, which is the key to micro-nano technologies [1]. Fiber optic displacement sensors have many applications in positioning and distance control, in detecting linear and angular movement, pressure, temperature and vibration [2]. Two methods are commonly adopted for displacement sensing, namely laser interferometry and intensity modulation of reflected light. Laser interferometry is based on the phase modulation and fringe counting method. It has high resolution and stability, but its precision and stability depends on the wavelength of light [3]. Comparatively, the reflective intensity modulation technique is significantly simpler method for non-contact displacement measurements and provides high resolution [4].

As far as sensing applications are concerned plastic fibers have inherent advantages like ease of handling, coupling and termination over the silica fibers. They have high resistance to fracture and are easy to polish and cut [5]. The important parameters deciding the performance of the sensor are the fiber parameters as well as geometrical parameters of the sensor [6-8].

In this paper, the effect of one of the geometrical parameter that is offset between the transmitting fiber and receiving fiber on the performance of plastic two-fiber displacement sensors is studied experimentally by keeping the all other parameters constant.

2. Experimental setup

The Schematic in Fig. 1 depicts a typical experimental setup for the reflective intensity modulation dual fiber probe displacement sensor. It consists of a light source, a fiber optic probe, a photo detector, a micrometer, a reflecting surface a transimpedance amplifier and a multimeter.

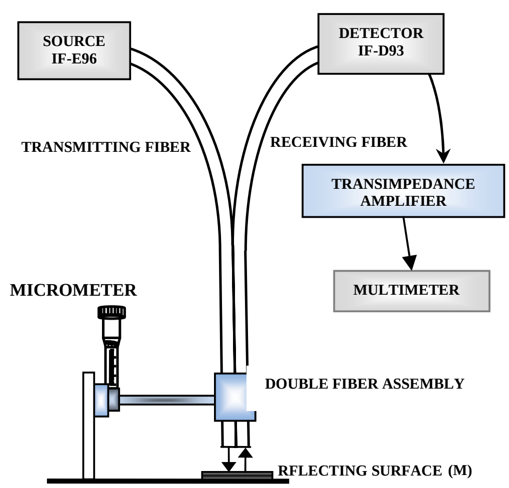

Fig. 1. The schematic experimental setup.

A light source of peak wavelength 660 nm (IF-E96) and the photo detector (IF-D93) were used. The fiber optic probe consists of two multimode plastic fibers, one Transmitting (T-fiber) and other for Receiving (R-fiber). A flat reflecting surface was utilized as a target to reflect back the conical shape incident light from the T-fiber to the R-fiber. The light source is coupled into the T-fiber and the light received by the R-fiber is incident on the photo detector. The photoconductive transimpedance amplifier was used to convert the intensity of light into equivalent voltage signal. A multimeter was used to display the output voltage. Micrometer stage was used to move the probe from the reflecting surface in steps of 50µm.

In this experiment, the sensor should be mounted perpendicular to the reflecting surface (M) and flush against the surface. At worst, the output voltage of the sensor in this position should be close to zero. Then the axial micro-displacement of the sensor was varied in steps of 50µm and the transimpedance amplifier output voltage of the reflected light was noted using multimeter. The length difference between T-fiber and R-fiber at the probe end is called the offset (k) and is shown in Fig. 2.

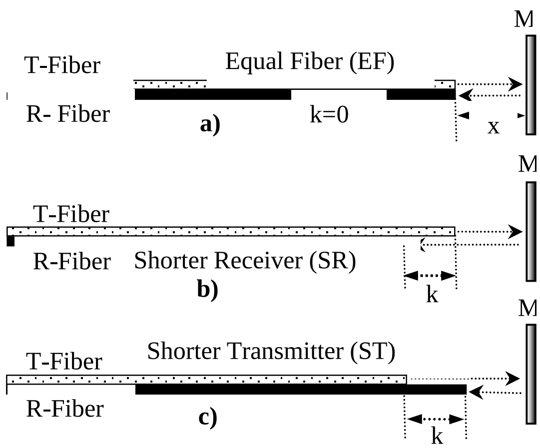

Fig. 2. Three configurations of two-fiber probe a) Equal Fiber (EF) b) Shorter Receiver (SR) c) Shorter Transmitter (ST).

In the Shorter Receiver (SR) configuration, T-fiber is ahead of R-fiber. When R-fiber is ahead than T-fiber, it is Shorter Transmitter (ST) configuration. Keeping all other parameters fixed, and varying the offset in steps of 0.5 mm the output power was measured in both configurations. For the fibers used the core/clad diameters is 980/1000µm, protecting jacket thickness is 0.6mm and NA=0.51. The reflected intensity modulation of the sensor for the axial displacement 'x' between the fiber probe tip to the reflector is noted for different configurations that are Equal Fiber (EF), SR and ST.

3. Resutls and discussion

Fig. 3 and Fig. 4 shows the results of the SR and ST configurations for the reflected light intensity as a function of the displacement for different fiber offsets of 0, 0.5, 1 and 1.5mm about dynamic range of 20 mm respectively. Each response curve starts from a near zero value and reaches a maximum at a particular axial distance and then drops slowly to a minimum value. Table 1 and Table 2 shows the performance values of the SR and ST configurations respectively.

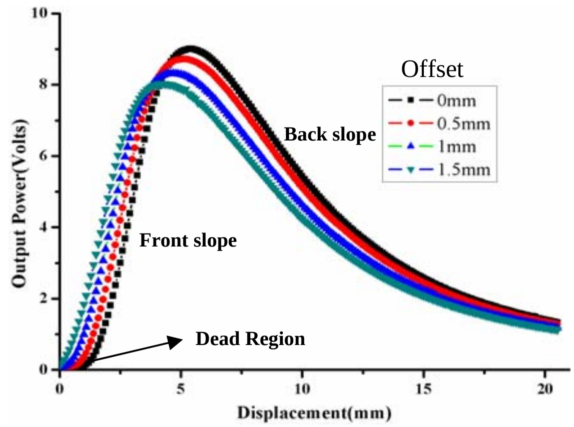

Fig. 3. Reflection intensity versus axial distance for different offset values for SR configuration.

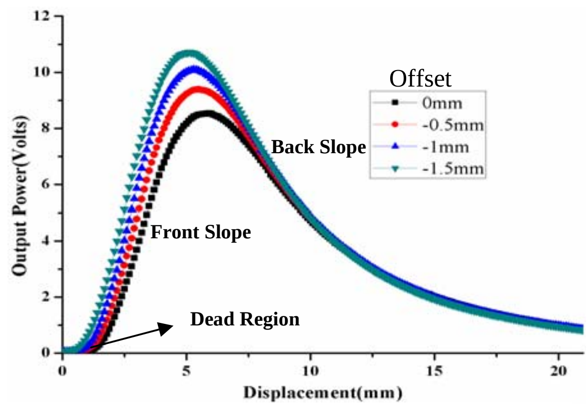

Fig. 4. Reflection intensity versus axial distance for different offset values for ST configuration.

For a change in the offset value three major changes are observed in the displacement intensity curve. First, the dead region distance is considerably decreased on increasing the offset value in both SR and ST configurations. Second point and perhaps the most important is the shift of the peak intensity to shorter distances and decrease in the maximum output power with increase in the offset value in SR configuration, where as in ST configuration it is shifted to shorter distances and increase in the maximum output power with increase in the offset value as shown in Fig. 5 and Fig. 6. Third point is the sensitivity of front and back slopes are decreased with increase in the offset value for dynamic range of 2 mm and 5.7 mm linear regions respectively in SR configuration. Where as in ST configuration the sensitivity of front and back slopes are increased with increase in the offset value for dynamic range of 2 mm and 4.2 mm linear regions respectively as shown in Fig. 7.

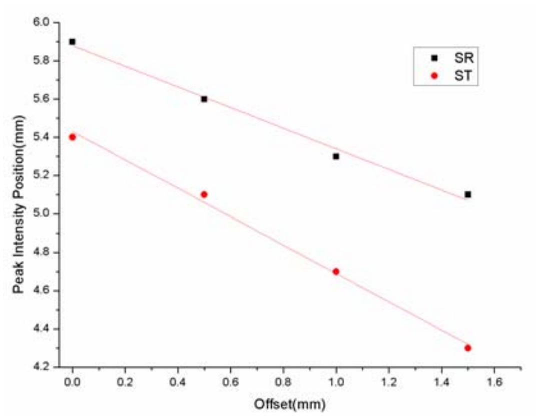

Fig. 5 Peak Intensity position for offset.

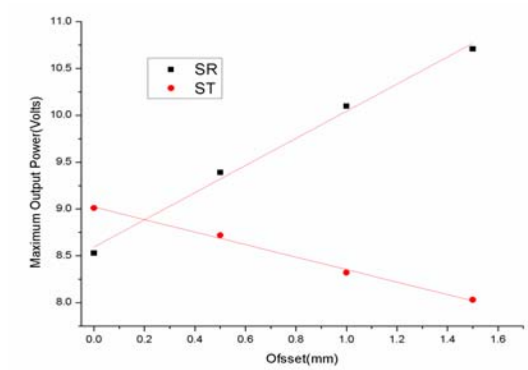

Fig. 6. Maximum output power for offset.

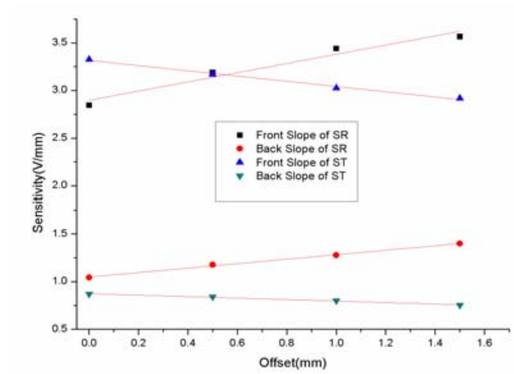

Fig. 7 Front and Back slopes for offset.

From Table 1 and Table 2 it is evident that the FWHM is unaffected with offset in both SR and ST configurations. It is also evident that the dynamic range is constant for front slope and back slope regions for both SR and ST configurations. The offset can be used to change any parameters discussed above without changing the dynamic range. The blind region of the sensor can be minimized using offset and this is very easy to change the offset than the tilting of the two fibers.

Table 1. The Performance characteristics of the SR configuration at different offset (k) values.

Offset (mm)	Front Slope			Back Slope			Maximum Output (V)	Peak Intensity Position (mm)	FWHM (mm)
	Sensitivity (V/mm)	Dynamic Range (mm)	Linearity	Sensitivity (V/mm)	Dynamic Range (mm)	Linearity			
0	3.3273	2	0.9983	0.8686	5.7	0.9984	9.01	5.4	5.8
0.5	3.1707	2	0.9983	0.8417	5.7	0.9981	8.72	5.1	5.8
1	3.025	2	0.9983	0.7983	5.7	0.9985	8.32	4.7	5.8
1.5	2.9191	2	0.9983	0.7538	5.7	0.9986	8.03	4.3	5.8

Table 2. The Performance characteristics of the ST configuration at different offset (k) values.

Offset (mm)	Front Slope			Back Slope			Maximum Output (V)	Peak Intensity Position (mm)	FWHM (mm)
	Sensitivity(V/mm)	Dynamic range (mm)	Linearity of Front slope	Sensitivity (V/mm)	Dynamic range (mm)	Linearity			
0	2.8441	2	0.9987	1.0427	4.2	0.9981	8.53	5.9	4.7
0.5	3.188	2	0.9987	1.1775	4.2	0.9981	9.39	5.5	4.7
1	3.4402	2	0.9987	1.2776	4.2	0.998	10.1	5.3	4.7
1.5	3.5654	2	0.9987	1.4	4.2	0.998	10.71	5.1	4.7

4. Conclusion

The experimental results of the EF, SR and ST configurations were studied. SR configuration shows less dead region and the output power decreases and also shifts towards lower displacements for increase in the offset value. ST configuration shows very small difference in dead region and the output power increases and also shifts towards the lower displacements for increase in the offset value but very less compared to SR configuration. The sensitivity can be changed by changing the offset without changing the linear dynamic range of front slope and back slope. The dead region of the sensor can be minimized using offset.

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