INFLUENCE OF GEOMETRICAL PARAMETERS ON THE TRANSMISSION CHARACTERISTICS OF A U-SHAPED GLASS PROBE: DETERMINATION OF THE SENSITIVITY OF AN EXTRINSIC FIBER OPTIC REFRACTOMETER

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ABSTRACT: The Novel approach of present day sensors lies in their capability of determining the environmental parameters with highest possible sensitivity. This paper reports the measurement of sensitivity of an intensity modulated fiber optic sensor by varying the prong widths of a U-shaped glass rod with various diameters used as a sensing element. U-shaped borosilicate glass rod with a prong width of 17mm was connected to a light source of 630nm wavelength at one side and a Bench mark optical power meter on the other side by using 200/230 µm Step Index PCS fibers. Initially the output power was noted, when the light launched from the source which transmits through the U-shaped glass rod and coupled to the optical power meter, when the air is surrounding the glass rod. The experiment was repeated and the values of output power was tabulated by connecting the U-shaped glass rods with various prong widths in between the light source and optical detector by fixing the other geometrical parameters to remain same. At the same time the refractive index of air was taken as 1.00028 as standard value. In the second stage of experimentation, the setup with U-shaped rod was immersed in a container filled with distil water of height 25mm and output power was noted. The process was repeated by using the setup with U-shaped glass rods of different prong widths and water surrounding the glass rod. Height of the distil water surrounding the U-shaped glass rod was consider in the third stage of the experimentation. By considering the above geometrical parameters of the U-shaped glass rod, the sensitivity of the sensor was calculated and concluded that the sensor operated by offering highest sensitivity when width between two prongs is reduced and height of the immersion of liquid is increased.

KEYWORDS: **Environmental Parameters, Geometrical Parameters, Height of the immersion, Prong width, Refractive Index, Sensitivity, U-shaped glass rod.**

I. INTRODUCTION

The progress of biotechnology, information technology and photonics has necessitated the investigation for a new sensor system employing optical fibers. The fiber optic sensor systems use various optical fibers to guide the light in the wavelength range between 180nm to 10µm depending on the material of the core of the optical fiber. The main role of the fiber optic sensor is to convert the magnitude of some environmental parameter into a change in the magnitude of light parameter such as phase, intensity, wavelength and frequency which can be measured more conveniently and accurately. Depending on the change in the parameter of the light corresponding to the interaction with a measurand, fiber optic sensing techniques can be classified into four types, they are interferometric, intensity modulation, fluorescence and spectral modulation. Optical fiber sensors can be broadly classified into extrinsic fiber optic sensors and intrinsic fiber optic sensors. The modulation of the light parameter takes place inside the fiber in case of intrinsic sensors. Whereas in an extrinsic sensor the modulation take place outside the fiber. In the extrinsic sensors the optical fiber merely acts as a conduit to transport the light signal to and from the sensor head.

Some of the key features of fiber optic technology as compare to electrical sensors are sensed signal is immune to EMI and RFI. The fiber optic sensors are safe in explosive environment, highly reliable and secure. They offer high voltage insulation, low volume and weight. They can be used as a point sensor. They are resistance to nuclear and ionizing radiation. Hence they play a major role in future medical, industrial and aerospace and consumer application [1-4]. In the general configuration of an intensity modulated sensors, the base band signal (the measurand) will modulate the intensity of light transmitted through the sensor[5]. The modulation will be reflected in the output of the detector which upon calibration can be used to retrieve measure of the measurand. The intensity modulation of light can be achieved through variety of schemes such as intensity modulation through light interruption[6-9], shutter/schlieren multimode fiber optic sensors[10], reflective fiber optic sensors[11-13], evanescent-wave fiber sensors [14-17], microbend optical fiber sensors [18-19], fiber optic refractometer [20].

The study of refractive index play a prominent role in medical, pharmaceutical, plastic, industrial fluid, food, petro chemical and beverage industry applications. In all the above applications the sensitivity of the refractometer is crucial in measuring various parameters. Various geometrical construction based optical fiber sensors are available for wide range of industrial applications [21-24]. It is possible to design innovative fiber optic refractive index sensor that has unique properties using fiber optic technology and micro optics. Takeo et al [25] have reported a fiber optic refractometer in which a plastic clad silica (PCS) fiber has been bent into the form of an U-shape by removing plastic cladding from a section of the fiber.

II. EXPERIMENTAL DETAILS

The basic experimental arrangement consist of input light source operating at 630nm, a bench mark light detector and sensing system having two PCS fibers of 200/230µm and a U-shaped borosilicate glass rod as shown in fig.[1].

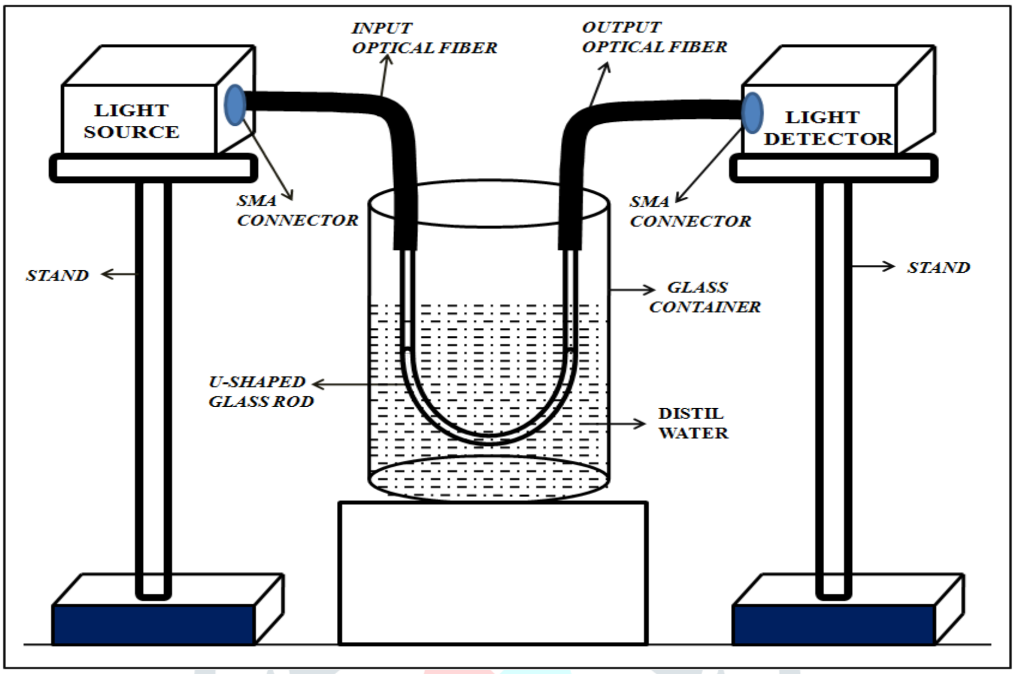

Fig.1: Experimental arrangement of U-shaped glass rod based Fiber Optic Refractometer

Parameters of U-shaped glass rod:

Thickness of rod:	1mm
Total height of the glass rod:	40mm
Height of the glass rod immersed in liquid:	25mm

The U-shaped glass rod of 1mm diameter connected in between the light source and the power detector by using PCS optical fibers. The light launched from the source will travel through the input fiber arm and coupled to one of the ends of the U-shaped glass rod and couples out into the output fiber arm and enters into the power detector when the air is surrounding the U-shaped glass rod. The power was noted from the detector and was recorded. At this movement the refractive index of air is also recorded as 1.00028 as a standard value. The setup with prong width of 17mm glass rod was immersed in a container consisting of distil water of height 25mm. The light was launched into the sensing system and power reaching the detector was noted. This time while light traveling through the U-shaped glass rod will interact with a medium i.e. liquid (distil water) of higher refractive index(1.33299) than the air. A portion of light will be absorbed in the liquid whose amount is greater than when air is surrounding the rod due to the increase in refractive index. This process is repeated by using different U-shaped glass rods of different prong widths.

Parameters of U-shaped glass rod:

Thickness of rod:	0.5mm
Total height of the glass rod:	40mm
Height of the glass rod immersed in liquid:	25mm

The experimental process was repeated by using U-shaped glass rod with various prong widths as above but with a rod thickness of 0.5mm.

Sensitivity with respect to prong width:

The sensitivity of the sensor by changing the prong widths of the U-shaped glass rod by fixing the thickness of the rod 1mm was determined and compared with the sensitivity of the sensor by changing the prong width of the U-shaped glass rod by fixing the thickness of the rod as 0.50mm. The comparison between 1mm thickness of U-shaped glass rod and 0.50mm glass rod shows that 0.50mm thickness U-shaped glass rod offers higher sensitivity than U-shaped glass rod with 1mm thickness.

Change in the height of immersion of the U-shaped glass rod:

The experimental process was repeated by increasing the height of immersion of the U-shaped glass rod into the liquid (distil water) by keeping all other parameters remain same as shown in Fig.[2].

Thickness of rod:	0.5mm
Total height of the glass rod(H):	40mm
Height of the glass rod immersed in liquid(h):	4 – 25mm
Width between two prongs(Z):	5mm
Radius of the Curvature(X):	2.5mm
Depth of the Curvature(Y):	2.5mm

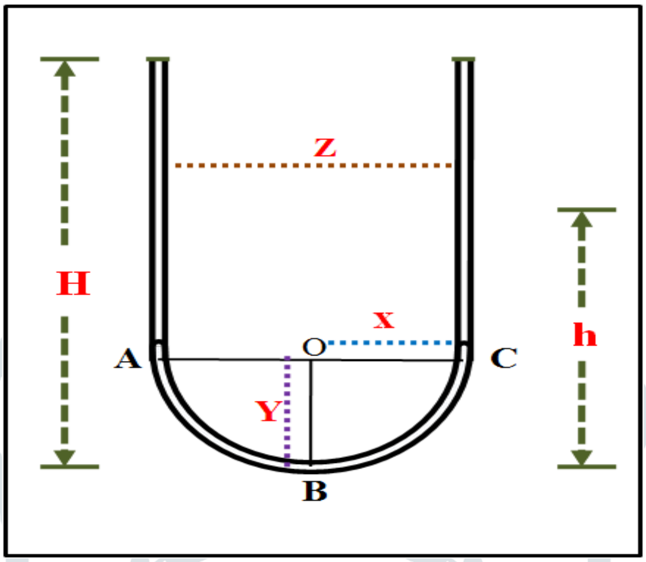

Fig.2: Geometrical parameters of the U-shaped glass rod

III. RESULTS AND DISCUSSION

The experimentation was carried out in three parts. In the first part the air is used as a measurand and the diameter of the glass rod fixed as 1mm which brings the corresponding change in the output power. The air modulates the intensity of the light in a fixed manner as its refractive index is fixed (1.00028). This is done with various prongs widths of U-shaped glass rod and with distill water surrounding the glass rod. The output power values are noted and tabulated in table[1].

Sensitivity(α): Sensitivity of the sensor depends upon its superiority to measure smaller change in the environmental parameters. A change in the magnitude of measuring parameter corresponding to a change in the measurand parameter.

$$\text{Sensitivity } (\propto) = \frac{\text{Change in the magnitude of measuring parameter}}{\text{Change in the magnitude of measurand parameter}}$$

$$\text{Sensitivity of the developed refractive sensor } (\propto_n) = \frac{\text{Change in Output Power}}{\text{Change in Refractive Index}} = \frac{dP}{dn}$$

Refractive Index of Air = 1.00028
Refractive Index of Distil water = 1.33299
Change in Refractive Index (dn) = 0.33271

Table-1: Thickness of the U-shaped glass rod: 1mm, Width between two prongs (17mm–5mm), Output power(dBm) when air and distil water is around the glass rod, Change in the output power(dP), Sensitivity(α_n).

S. No.	Width between two prongs (mm)	Output Power (dBm)		Change in Output Power (dP)	Sensitivity($\propto_n$) $\frac{dP}{dn}$
		When Air is around the glass god	When Distil water is around the glass rod		
1	17	-28.4	-29.7	1.3	3.90731
2	15	-28.5	-29.9	1.4	4.20787
3	13	-28.6	-29.8	1.5	4.50843
4	11	-28.8	-30.5	1.7	5.10955
5	9	-29.0	-30.8	1.8	5.41012
6	7	-29.2	-31.1	1.9	5.71068
7	5	-29.4	-31.5	2.1	6.31180

From the readings in the table-1, as the width between the two prongs of the U-shaped glass rod decreases the power output decreases and change in the output power increases and also sensitivity increases shown graphically in fig.[3&4].

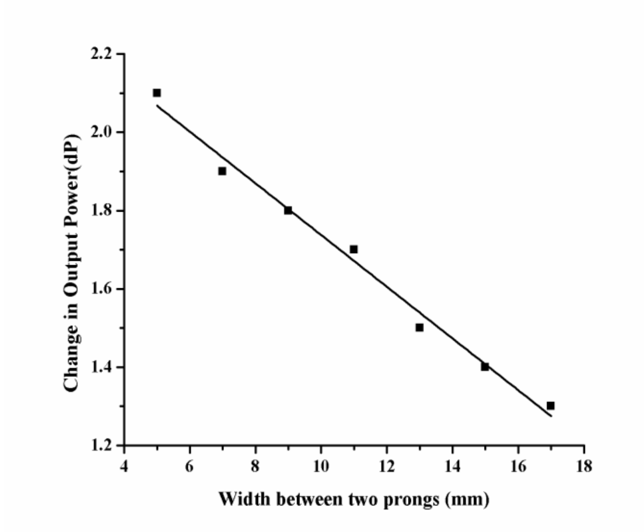

Fig.-3: Relation between Width between two prongs Vs Change in output power (dP)

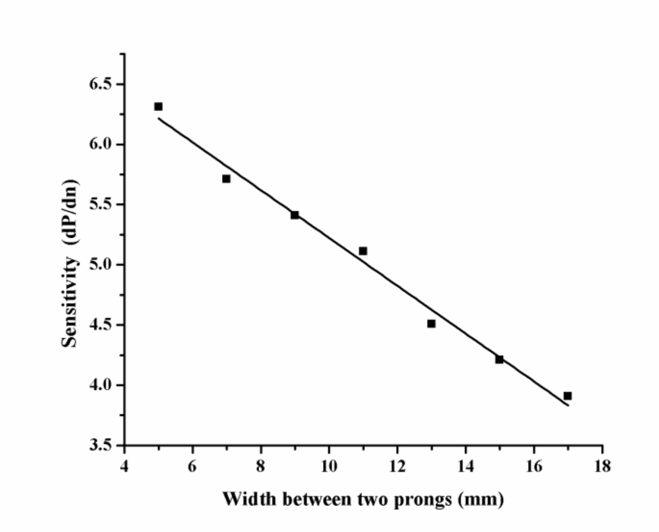

Fig.-4: Relation between Width between two prongs Vs Sensitivity (dP/dn)

Experiment was repeated with 0.5mm thickness and values are tabulated in table-2 and relation between prong width Vs change in the output power and sensitivity shown in graphically in fig-[5&6].

Table-2: Thickness of the U-shaped glass rod: 0.50mm, Width between two prongs (17mm–5mm), Output power(dBm) when air and distil water is around the glass rod, Change in the output power(dP), Sensitivity(α_n).

S. No.	Width between two prongs (mm)	Radius of Curvature (mm)	Output Power (dBm)		Change in Output Power (dP)	Sensitivity($\propto_n$) $\frac{dP}{dn}$
			When Air is around the glass god	When Distil water is around the glass rod		
1	17	8.5	-32.6	-34.3	1.7	5.10955
2	15	7.5	-32.7	-34.5	1.8	5.41012
3	13	6.5	-32.8	-34.7	1.9	5.71068
4	11	5.5	-33.0	-35.0	2.0	6.01124
5	9	4.5	-33.2	-35.3	2.1	6.31180
6	7	3.5	-33.5	-35.7	2.2	6.61236
7	5	2.5	-33.8	-36.2	2.4	7.21349

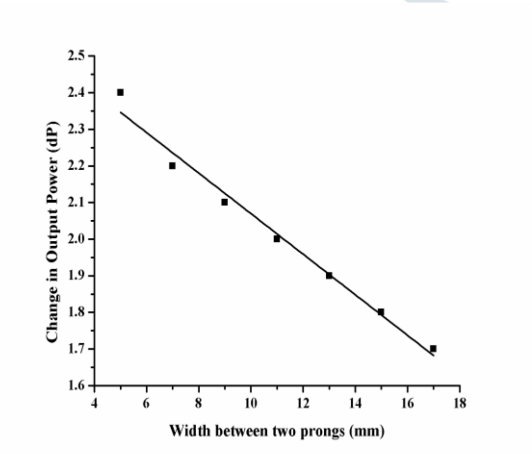

Fig.-5: Relation between Width between two prongs Vs Change in output power (dP)

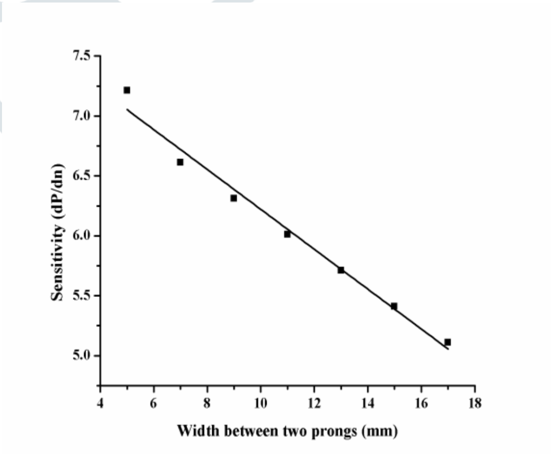

Fig.-6: Relation between Width between two prongs Vs Sensitivity (dP/dn)

Experiment was repeated with changing the height of the immersion of the U-shaped glass rod of thickness 0.5mm and keeping other geometrical parameters remain same. Values are tabulated in table-3 and relation between prong width Vs change in the output power and sensitivity shown in graphically in fig-[7&8].

Table-3: Thickness of the U-shaped glass rod: 0.50mm, Height of the glass rod immersed in liquid (4mm–25mm), Output power(dBm) when air and distil water is around the glass rod, Change in the output power(dP), Sensitivity(α_n).

S. No.	Height of the glass rod immersed in liquid (mm)	Output Power (dBm)		Change in Output Power (dP)	Sensitivity($\propto_n$) $\frac{dP}{dn}$
		When Air is around the glass god	When Distil water is around the glass rod		
1	4	-33.8	-34.0	0.2	0.60112
2	7	-33.8	-34.2	0.4	1.20225
3	10	-33.8	-34.5	0.7	2.10393
4	13	-33.8	-34.8	1.0	3.00562
5	16	-33.8	-35.1	1.3	3.90730
6	19	-33.8	-35.4	1.6	4.80899
7	22	-33.8	-35.8	2.0	6.01124
8	25	-33.8	-36.2	2.4	7.21349

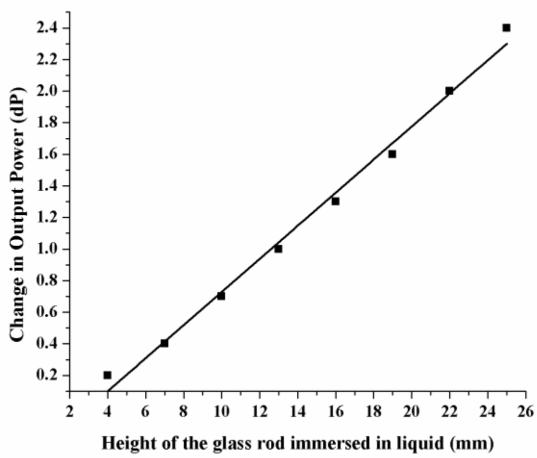

Fig.-7: Relation between Width between two prongs Vs Change in output power (dP)

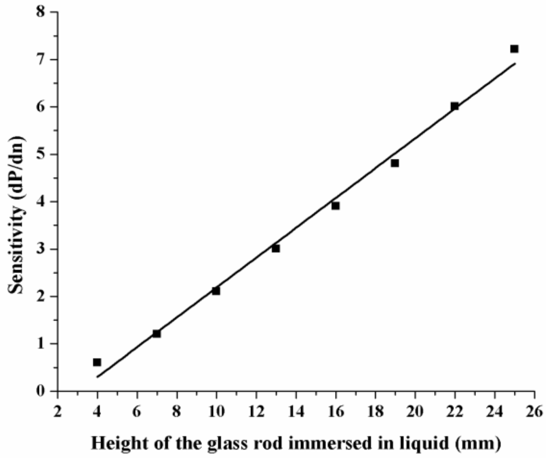

Fig.-8: Relation between Width between two prongs Vs Sensitivity (dP/dn)

IV. CONCULSION

From table 2&3 and from graphs 2,4&6 it is observed that as the width between two prongs decreases the sensitivity increases and as the height of the immersion of the glass rod increases the sensitivity also increases. Hence an extrinsic fiber optic sensor consisting of a U-shaped glass rod as an extrinsic element, it offers higher sensitivity as prong width decreases and height of the immersion increases.

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