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ANALYSIS OF SENSITIVITY OF AN EXTRINSIC FIBER OPTIC SENSOR BASED ON U–SHAPED GLASS RODS WITH DIFFERENT GEOMETRIES EMPLOYED AS SENSING ELEMENTS USING BINARY LIQUIDS AT 660NM WAVELENGTH

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Abstract: *The sensitivity of an extrinsic fiber optic liquid refractive index sensor is analyzed considering various designs of U-Shaped glass rods employed as sensing elements using binary liquids at the operating wavelength of 660nm in the present paper. The influence of geometry, thickness, macro-bend and radius of the glass rod, on the sensitivity of the sensor is investigated experimentally. The sensor is constructed by connecting the U-Shaped glass rods of different geometries at the middle of a simple fiber optic link using a light source of 660nm wavelength using two PCS fibers. At the tight bends, some of the light not to be internally reflected back into the core but to propagate into the cladding and be lost. The losses would decrease rapidly for less tight bends. In case of large core (glass rod) the losses in the transmitted signal decreases and accordingly the sensitivity decreases. The losses in the fiber increase with decrease in the bend radius of the fiber and hence for U-shaped fiber sensitivity is more comparing with the straight fiber of infinity radius. The relationship between bending radius and sensitivity, an inverse square law relationship can be formulated.*

Key words: Influence of geometry, Macro-bend, Radius of the glass rod, Sensitivity, Thickness of the glass rod, Various designs of U-shaped glass rod.

1. Introduction

Because of the wide spread applications and advantages over the conventional sensors, the intensity modulated fiber optic sensors are of considerable interest across the globe for past few decades [1–5]. These sensors exploit interaction between the absorbing medium present there and the field penetrating into the external region of the glass fiber. The launched into the fiber has the wavelength close to the peak absorption wavelength surrounding the glass probe. Due to the absorption of the evanescent wave penetration into the absorbing medium, this results in the loss of the transmitted power. The concentration of the absorbing fluid is measured by the optical attenuation along the fiber. the penetration depth of the evanescent field in the sensing region and the number of ray reflections per unit length of the bare fiber causes the evanescent wave absorption and hence the sensitivity of the sensor for a given

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length of the glass fiber. The sensitivity field is very weak as the sensitivity of the sensor is limited in the case of straight and uniform sensing probe. Various authors have suggested the use of the fiber into U shape, the tapering of the sensing region, the use of launching angle of the light into the fiber to increase the sensitivity [6]. The results of experimentation so far reported the use of any kind of probe geometry indicating the deviation from the Beers law of absorption and nonlinear dependence of evanescent absorption [7–11]. It is reported in the literature that due to non-linearity, the experimental results could not be explained by the Beers law based evanescent wave model. Hence we should choose a fluid with negligible absorption for the experiment to have more realistic comparison.

The experimental investigation of the glass fiber evanescent wave absorption sensor based on various shapes of probes has been reported in the present paper. The solution of methanol in benzene has been selected as the test fluid to have the negligible contribution of the adsorption on the response curve. The variation of output power on several shaped glass probes and hence the sensitivities have been studied experimentally. The effect of bending radius U- shaped probe on the sensitivity has experimentally been studied and found that it is following the power law relation. On the basis of the theoretical principles, the results obtained were explained.

2. Experimental

Connected the second PCS fiber which in turn connected to a power meter. Benzene mixed in methanol is used as guiding medium in the sensing zone of the sensor. Initially, the bottom end of glass probe is immersed in benzene of 10 ml in volume poured in a beaker. From the input end of the sensor, power is launched and the output power is noted. 1ml of benzene is removed from the beaker and same quantity of methanol is added to the benzene and mixed thoroughly and the output power is noted again. Keeping the total volume of benzene and methanol mixture equal to 10 ml, the experiment is continued. The transmitted power through the fiber was measured separately for benzene solution (P_1) and methanol solution (P_2) and (methanol + benzene) solution (P_3). The evanescent absorption coefficient can be determined from these values along with the length of the fiber probe from the following relation. The basic components in the experimental arrangement of a uniform U-shaped glass rod based fiber optic extrinsic sensor are shown in figure [Fig. 1].

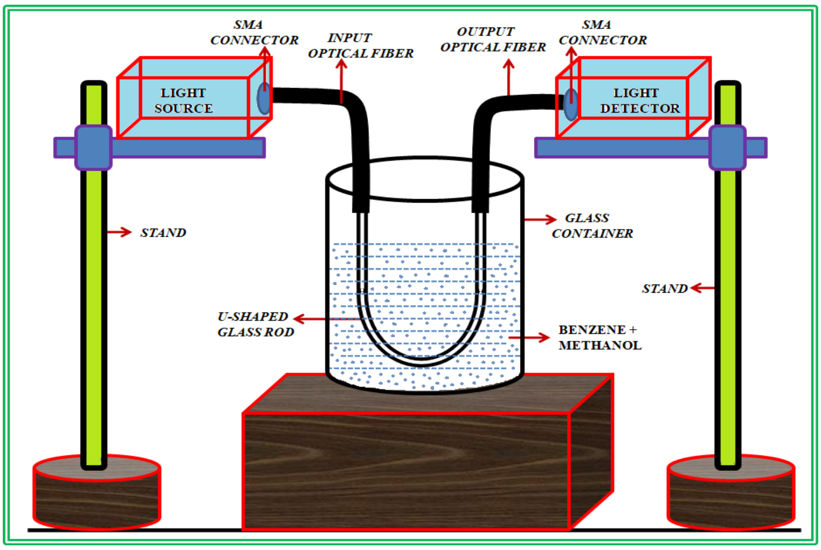

Fig.1: Experimental arrangement of U–shaped glass rod sensor.

Different shapes of the glass rod sensing elements to be used in the present study have been shown [Fig. 2].

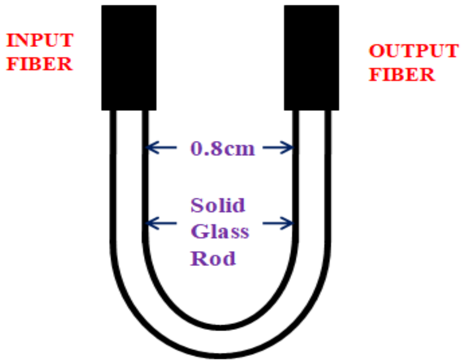

Fig.2(a): U-Shaped glass rod (0.5mm Dia)

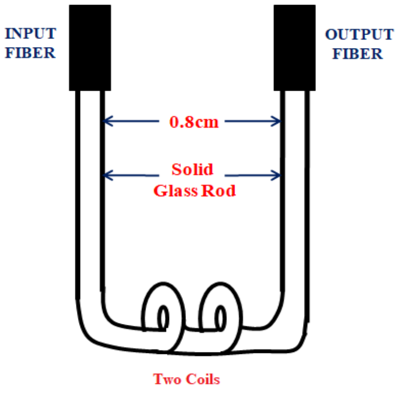

Fig.2(b): Coiled neck U-Shaped glass rod (0.5mm Dia)

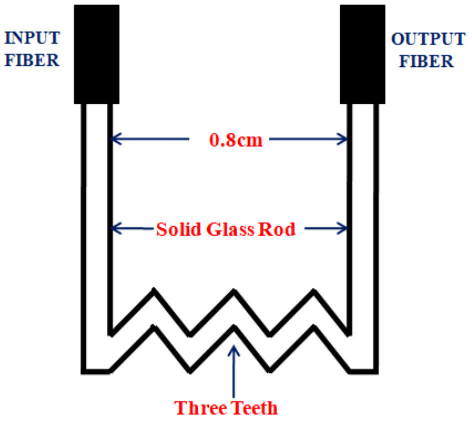

Fig.2(c): Saw tooth neck U-Shaped glass rod (0.5mm Dia)

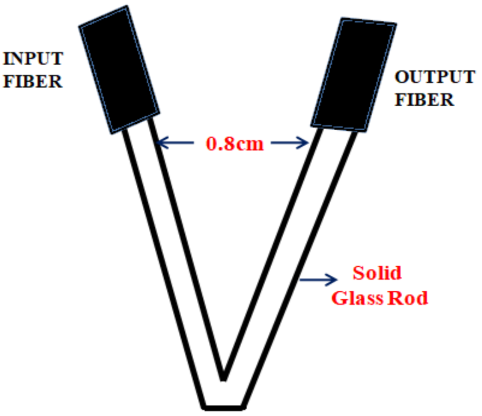

Fig.2(d):V-Shaped glass rod (0.5mm Dia)

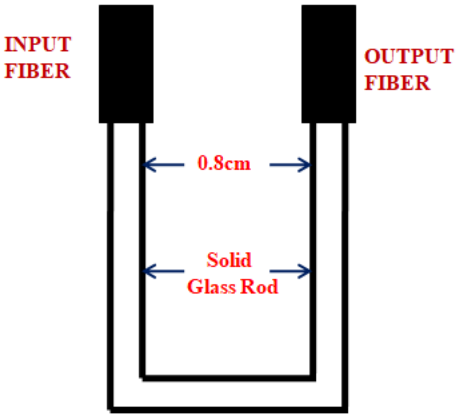

Fig.2(e): Square Shaped glass rod (0.5mm Dia)

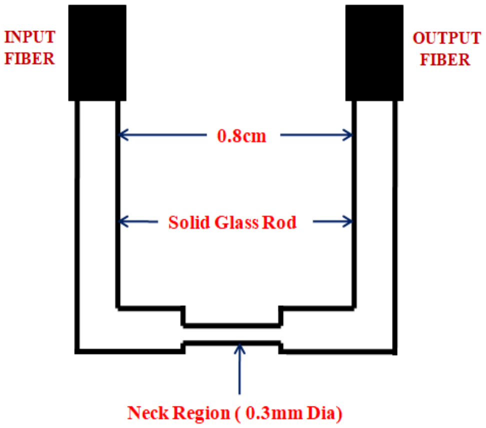

Fig.2(f): Shrinked neck U-Shaped glass rod (0.5mm Dia)

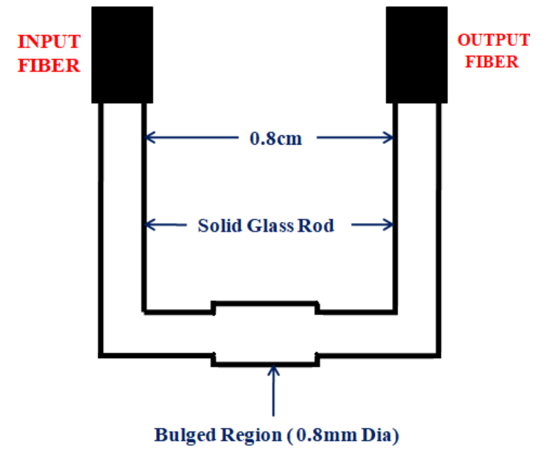	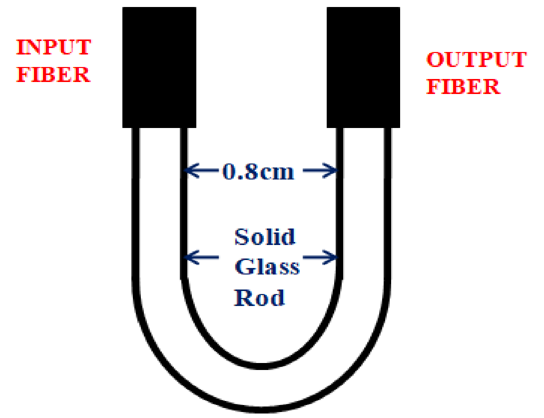
Fig.2(g): Bulged neck U-Shaped glass rod (0.5mm Dia)	**Fig.2(h):** U-Shaped glass rod (1 mm Dia)

Fig.2: Various designs and geometries of the sample used in the experimentation.

One of the ends of the glass rod which is bent into various shapes is coupled to PCS fiber which in turn connected to a light source operating at the wavelength of 660nm. The other end of the glass probe is

$$\alpha = \frac{2.303}{L}\log\left(\frac{P_1}{P_2}\right) \qquad (1)$$

The sensitivity of the evanescent field absorption is directly proportional to the evanescent absorption coefficient, for a concentration of absorbing fluid and the length of the sensing region [12]. Using the different fiber parameters and probe geometries, the values of the evanescent wave absorption coefficient can be used to compare the sensitivity to the sensors. The –Shaped probe used in the experimentation is shown in figure [2a]. The glass rod bent in the form of U is made of borosilicate glass of 0.5 mm diameter. The bending radius and uniformity were checked using travelling microscope. The experiment was performed only on these probes that were uniform and the bend was close to U – shape. The other forms of probes namely, V-shape, square shape, coiled neck U-shape, bulged neck U-shape, shrinked neck U-shape were also made of same quality glass and of 0.5 mm of diameter. Another U-shaped glass rod of 1 mm diameter also tried with a view to observe the variation in the fiber parameter.

3. Results And Discussion

The value of absorption coefficient for a given concentration of solution is larger in case of U-shaped probe which is in accordance with the results reported in literature [13]. The sensors response is found to be linear for U-shaped glass rod of bending radius 0.5 mm, indicates the absence of adsorption [Fig. 3]. The experiment is repeated to study the effect of the power output on the thickness of the glass probe another U-shaped glass rod of 1mm thickness is used. The value of the evanescent absorption coefficient is larger in the case of 1mm sized probe compared to a 0.5mm probe which evident from figures [3 & 4].

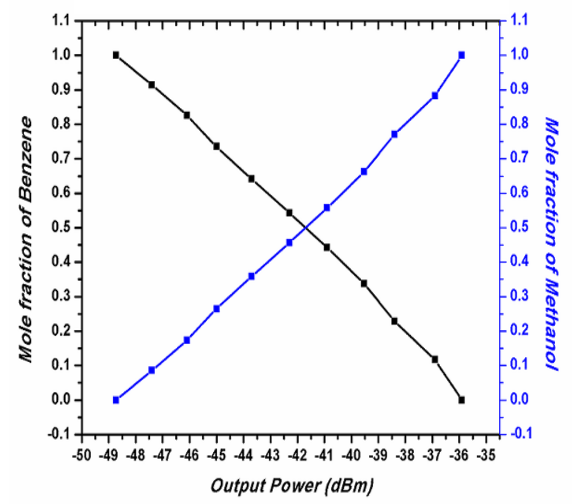

Fig.3: Relation between Mole fraction and Output Power (dBm) for U-shaped glass rod of 0.5mm diameter.

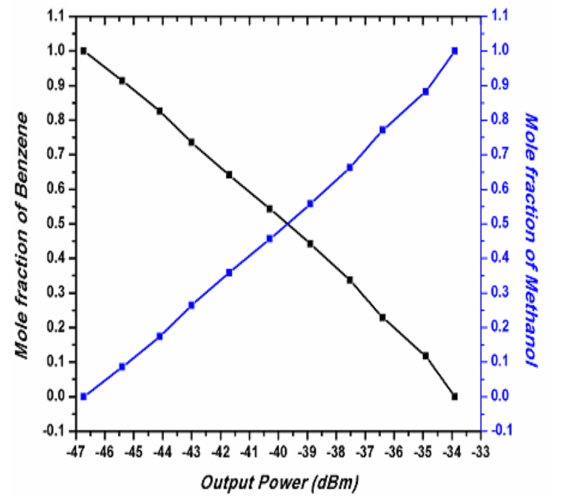

Fig.4: Relation between Mole fraction and Output Power (dBm) for U-shaped glass rod of 1mm diameter.

The experiment is further repeated as shown in figure [2b] and the corresponding graph is represented in figure [5] for a coiled neck U-shaped glass rod dipped in the same binary mixture.

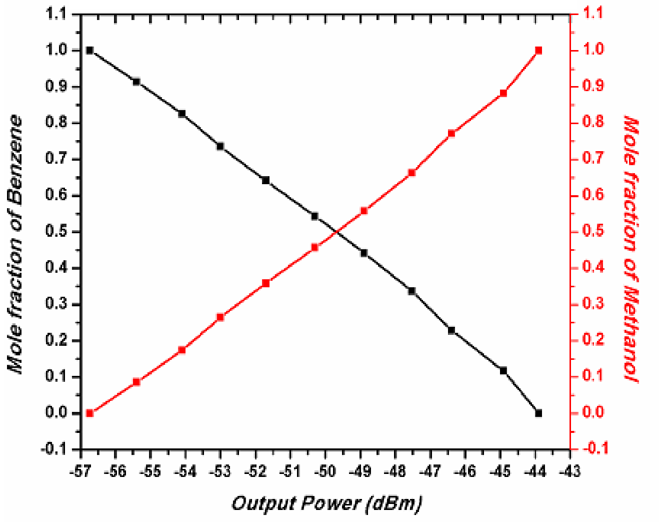

Fig.5: Relation between Mole fraction and Output Power (dBm) for Coiled U-shaped glass rod

This is due to the fact that the multiple micro-bending of the rod results in total loss of power into the liquid which can’t be retrieved. The graphs are presented in Fig [6-9] by repeating the experiment further with V-shaped glass rod [Fig. 2d] and straight neck U-shape (square shape) glass rod as indicated in figure [2e] and finally a shrinked neck U-shaped glass rod as indicated in figure [2f] and bulged nick U-shaped glass rod in figure [2g].

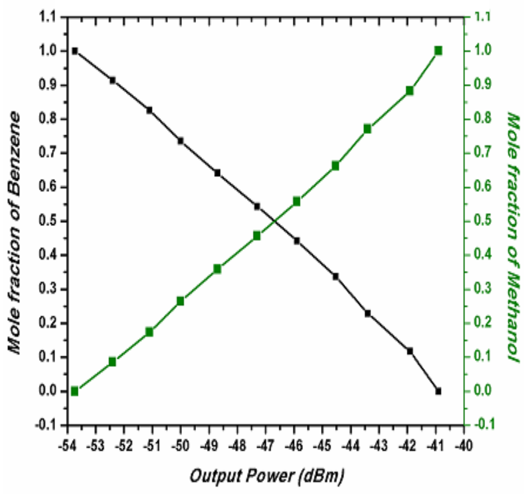

Fig.6: Relation between Mole fraction and Output Power (dBm) for V-shaped glass rod

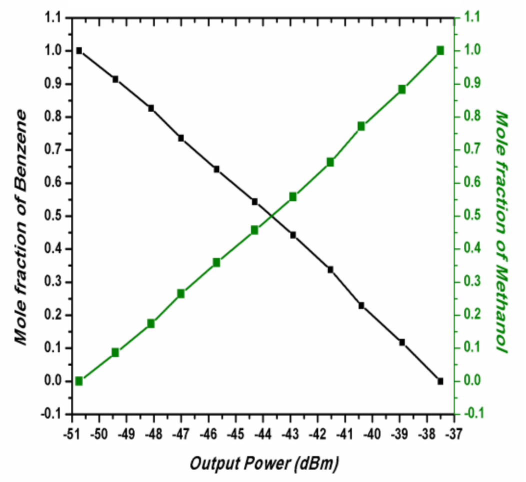

Fig.7: Relation between Mole fraction and Output Power (dBm) for Square shaped glass rod

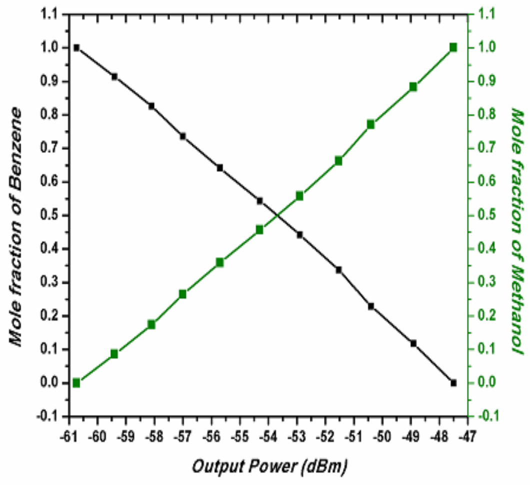

Fig.8: Relation between Mole fraction and Output Power (dBm) for shrinked neck U-shaped glass rod

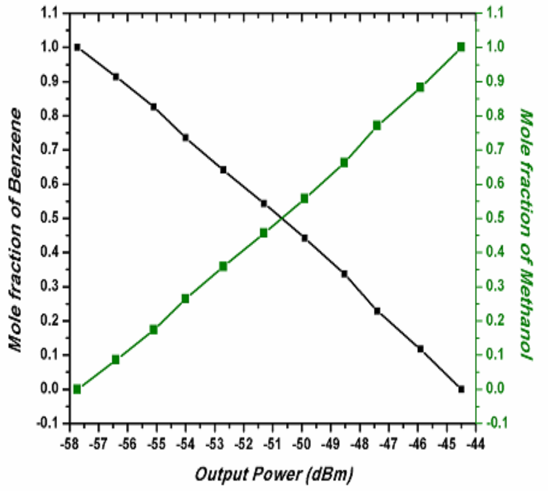

Fig.9: Relation between Mole fraction and Output Power (dBm) for bulged neck U-shaped glass rod

4. Conclusions

The sensitivity of the sensor affects the numerical aperture and hence the launching angle. The sensitivity of the sensor increases with increase in numerical aperture of the fiber. This fact has been observed for U-shaped probes with a solution of methanol in benzene as a test fluid. The sensitivity of the probe increases with the thickness of the glass rod and also with the decrease in bending radius. The sensitivity of the sensor depends on the core radius of the fiber and has maximum sensitivity depends on the bending radius of the fiber probe.

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