INVESTIGATION OF U-SHAPED GLASS ROD BASED INTENSITY MODULATED EXTRINSIC FIBER OPTIC SENSOR TO DETERMINE THE CONCENTRATION OF SUGAR

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ABSTRACT: In the present paper an intensity modulated extrinsic fiber optic evanescent wave sensor for the detection of content of sugar present in the solution of sugar mixed in Distil Water is presented. In the experimental setup two PCS fibers of 200/230µm dia, a Bench mark optical power meter, a light source operating at 630nm and a U-shaped glass rod of 0.5mm dia have been used. The U-shaped glass rod as an extrinsic sensing element was connected between light source and the power meter using two PCS fibers of 50cm length each. Fixing the height of immersion of U-shaped glass rod as 1cm, the power launched from the source and the power reaching the output detector was noted. With this immersion height the power was noted for various concentration of the sugar mixed in water. At the same time the refractive indices of the solutions with different concentration of sugar were determined by using Digital Refractometer (RX 7000i) operated at 5893Å. As the refractive index of the solution increases the output power decreases. This was repeated for various heights of immersion (2cm, 3cm) in the sugar solution. This sensor can be used in sugar industry and also in the civilian and consumer applications for the ready detection of the concentration of the sugar in various solutions.

KEY WORDS: **Bench mark Optical power meter, Content of sugar, Digital Refractometer (RX 7000i), Immersion height, PCS fiber.**

I. INTRODUCTION

In the past few decades fiber optic evanescent field absorption sensors have become popular for distributed and remote sensing applications [1-3]. The advantages and potentials offered by optical fibers in sensing and instrumentation are almost unlimited. Some of the key features of this advanced technology which offers substrantional benefits compare to conventional sensors are: inertness with chemicals, offers large bandwidth, effort remote sensing and distributing sensing, resistant to ionizing and nuclear radiation, used as point sensors and they occupy low volume and low weight, immune to RFI and EMI, safety in explosive environment, highly reliable and secure, high voltage insulation etc. Giallorenzi, Culshaw, Measures and Ghatak et al [4-7] have demonstrated the use of optical fibers as sensing device to sense vast range of parameters such as pressure, liquid level, temperature, antibodies, liquid refractive index, liquid pH, displacement, rotation, electric current, acoustic, magnetic and electric fields and so on. These sensors have found many application areas like military, industrial, medical, consumer, aerospace and a large civilian applications [8-11]. In the optical fiber sensors the process of transmission of light is based on the Attenuated Total Internal Reflection (ATIR) spectroscopy when a light transfers from denser to rarer medium. At the interface between denser and rarer medium the light totally reflects at the interface and the evanescent wave propagate parallel to the interface in the cladding with a characteristic depth of penetration and the amplitude of wave decreases exponentially in the rarer medium [12&13].

The intensity of the evanescent wave attenuates if the rarer medium is absorbing and gives rise to a decrease in the power propagating in the denser medium. With number of reflections at the interface increases the length of the fiber, the attenuation of the power also increases. Thus the optical fiber system with unclad portion as a sensing zone acts as a useful ATIR sensing element. Among the four types of optical fiber sensors the intensity modulated sensors offer the most wide spectram of sensors because the advantage of intensity modulated sensor lies in their simplicity of construction and their being compatible to the multimode fiber technology [14-16].

II. EXPERIMENTAL DETAILS

The Experimental arrangement of U-shaped glass rod based Intensity Modulated Extrinsic Fiber Optic Sensor (Fig. [1&2]) consists of three main basic elements.

1. The light source operating at 630nm wavelength.
2. The Bench mark optical power meter.
3. The sensing zone consisting of two optical PCS fibers of 200/230µm dia of 50cm length each connected to a U-shaped glass rod.

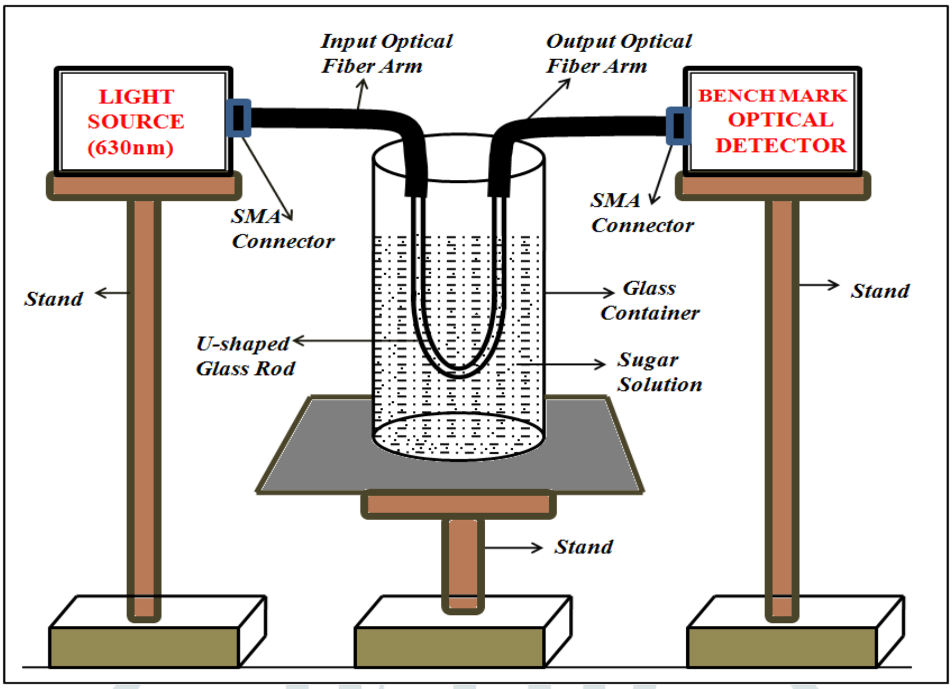

Fig.1: Experimental arrangement of U-shaped glass rod based Intensity Modulated Extrinsic Fiber Optic Sensor

Thickness of rod: 0.5mm

Total height of the glass rod(H): 40mm

Height of the glass rod immersed in sugar solution(h): 1cm, 2cm, 3cm

Width between two prongs(Z): 5mm

Radius of the Curvature(X): 2.5mm

Depth of the Curvature(Y): 2.5mm

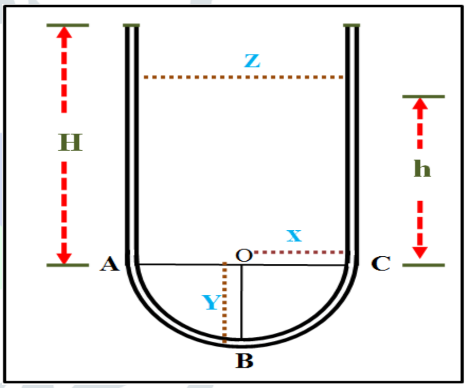

Fig.2: Geometrical parameters of the U-shaped glass rod

When light launched from the source transmits through the input fiber arm and couples into the U-shaped glass rod which is acting core and enters into the power meter and can be recorded in dBm scale. The light transmits without attenuation along the lengths of fiber and while it is propagating through the glass rod the light attenuates depending upon the nature of medium that surrounds the glass rod. The attenuation of the power along the length of the U-shaped glass rod also depends on the length of the liquid that surrounds the U-shaped glass rod core, as a cladding medium.

The experiment is under taken by using a sugar solution of known concentration poured in a container and exposed to a U-shaped glass rod. The refractive index of the solution with this concentration was noted by using Digital Refractometer (RX 7000i). The power is injected by switching "ON" the source and recording the power reaching the detector when air is surrounding. the U-shaped glass rod. This recorded value can be considered as power launched into the fiber, also power was noted when U-shaped rod of 1cm prong height placed in a wide mouth container. The sugar solutions are prepared by adding the sugar in steps of 1gm, 2gm, ……,10gm in the 10ml of water. Refractive index of each solution is recorded by using Digital Refractometer (RX 7000i) at the wavelength of 5893Å (sodium vapour lamp). Then power was noted from the detector by exposing the glass rod element to different solutions at a prong height of 1cm. The experiment was repeated by taking different core lengths by increasing height of the immersion of prongs of U-shaped glass rod.

III. RESULTS AND DISCUSSION

Readings are noted when the 10ml of water is exposed to the U-shaped glass rod and at this stage refractive index of water is noted as 1.33299 by using Digital Refractometer (RX 7000i). The power readings were noted down by launching the power into the sensing system and by exposing the U-shape glass core to sugar solutions of different concentrations of at a prong height of 1cm as shown in Table [1].

Height of the U-shaped glass rod immersed in sugar solution: 1cm

Output Power when air is surrounding the U-shaped glass rod: -33.8dBm

Table-1: Sugar content in 10ml Distil Water, Refractive index of Sugar solution, Output Power (dBm)and Power Loss (dB)

S. No.	Sugar content(gm) in 10 ml Distil Water	Refractive index of Sugar solution	Output Power (dBm)	Power Loss (dB)
1	0	1.33299	-34.5	0.7
2	1	1.34002	-34.9	1.1
3	2	1.34812	-35.3	1.4
4	3	1.35607	-35.7	1.9
5	4	1.36410	-36.1	2.3
6	5	1.37205	-36.6	2.8
7	6	1.38021	-37.1	3.3
8	7	1.38818	-37.6	3.8
9	8	1.39623	-38.1	4.3
10	9	1.40431	-38.6	4.8
11	10	1.41314	-39.2	5.4

The experiment was repeated by changing the depth of immersion of U-shaped glass rod into the sugar solutions as 2cm and 3cm, and the power values are recorded in Table [2&3]. The results are plotted graphically as shown in Fig. [3-5].

Height of the U-shaped glass rod immersed in sugar solution: 2cm
Output Power when air is surrounding the U-shaped glass rod: -33.8dBm

Table-2: Sugar content in 10ml Distil Water, Refractive index of Sugar solution, Output Power(dBm) and Power Loss (dB)

S. No.	Sugar content(gm) in 10 ml Distil Water	Refractive index of Sugar solution	Output Power (dBm)	Power Loss (dB)
1	0	1.33299	-35.6	1.8
2	1	1.34002	-36.0	2.2
3	2	1.34812	-36.4	2.6
4	3	1.35607	-36.8	3.0
5	4	1.36410	-37.2	3.4
6	5	1.37205	-37.7	3.9
7	6	1.38021	-38.2	4.4
8	7	1.38818	-38.7	4.9
9	8	1.39623	-39.2	5.4
10	9	1.40431	-39.7	5.9
11	10	1.41314	-40.3	6.5

Height of the U-shaped glass rod immersed in sugar solution: 3cm
Output Power when air is surrounding the U-shaped glass rod: -33.8dBm

Table-3: Sugar content in 10ml Distil Water, Refractive index of Sugar solution, Output Power(dBm) and Power Loss (dB)

S. No.	Sugar content(gm) in 10 ml Distil Water	Refractive index of Sugar solution	Output Power (dBm)	Power Loss (dB)
1	0	1.33299	-36.7	2.9
2	1	1.34002	-37.1	3.3
3	2	1.34812	-37.5	3.7
4	3	1.35607	-37.9	4.1
5	4	1.36410	-38.3	4.5
6	5	1.37205	-38.8	5.0
7	6	1.38021	-39.3	5.5
8	7	1.38818	-39.8	6.0
9	8	1.39623	-40.3	6.5
10	9	1.40431	-40.8	7.0
11	10	1.41314	-41.4	7.6

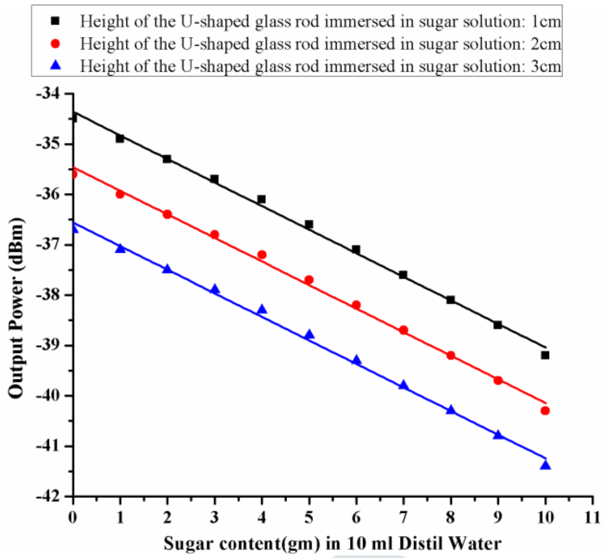

Fig.3: Graph between Sugar Content (gm) in 10ml Distil Water Vs Output Power(dBm) for 1cm, 2cm, 3 cm Height of the U-shaped glass rod immersed in sugar solution.

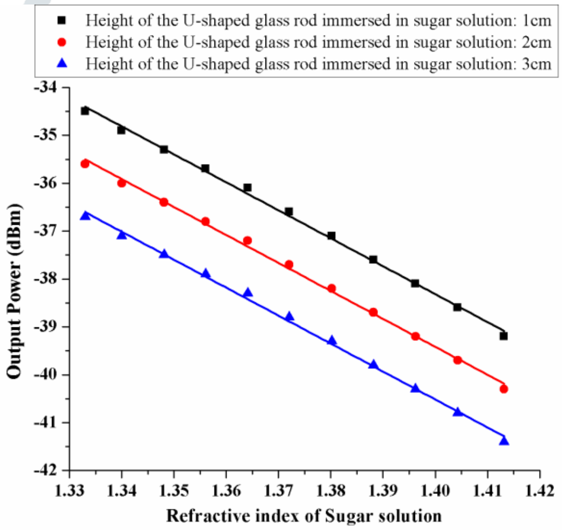

Fig.4: Graph between Refreactive index of Sugar solution Vs Output Power(dBm) for 1cm, 2cm, 3 cm Height of the U-shaped glass rod immersed in sugar solution.

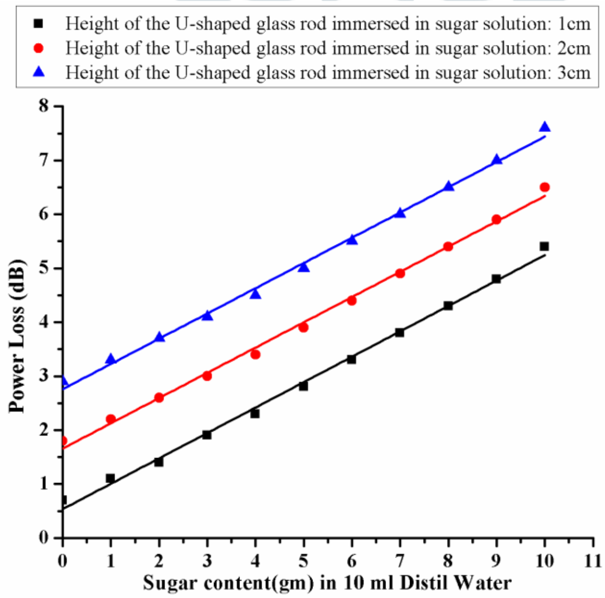

Fig.5: Graph between Sugar Content (gm) in 10ml Distil Water Vs Power Loss(dB) for 1cm, 2cm, 3 cm Height of the U-shaped glass rod immersed in sugar solution.

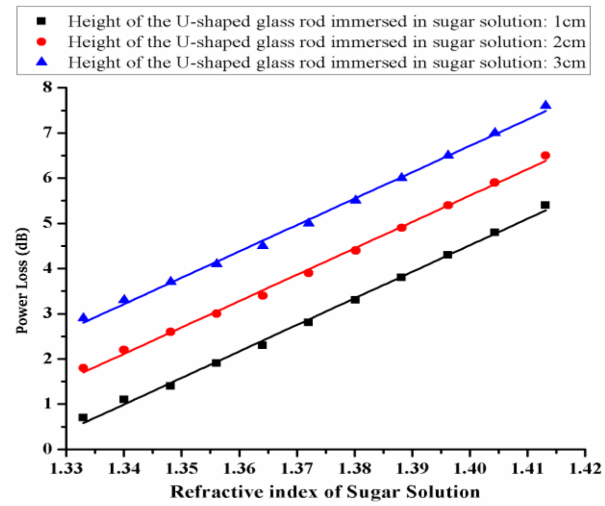

Fig.6: Graph between Refreactive index of Sugar solution Vs Power Loss(dB) for 1cm, 2cm, 3 cm Height of the U-shaped glass rod immersed in sugar solution.

IV. CONCULSION

From experimental data obtained and corresponding graphs, it can be noted that as the concentration of guided liquid increases the output power decreases. This is because as the refractive index of guiding liquid is directly proportional to the concentration. Much of the light will be absorbed in the guiding liquid with increasing the concentration and a less amount of the power reach the output detector. Hence the output power various with the refractive index and concentration of the solution which acts as a cladding around the U-shaped glass probe in the sensing zone. The study also reveals that as the length of the core in the sensing zone exposed to the sugar solution increases, the absorption of light also increases and hence the light reaching the detector decreases accordingly.

REFERENCES

[1] B D Gupta, C D Singh and A Sharma: "Fiber Optic Evanescent Field Absorption Sensor Effect of Launching Condition and Geometry of Sensing Region", Opt.Eng., Vol.33, No.6, pp.1864–1868 (1994).

[2] G Stewart, B Culshaw: "Optical Wave Guide Modeling and Design for Evanescent Field Chemical Sensors", Optics and Quantum Electron, Vol. 26, pp.249–259 (1994).

[3] P Radha Krishna, V P N Nampoori, C P G Vallabhan: "Fiber Optic Senor Based on Evanescent Wave Absorption, Opt. Eng., Vol.32, No.4, pp.692–694.

[4] T G Gillorenzi and S Ezekiel: "Special issue on optical fiber sensors", Optics News, Vol.15, No.11 (1989).

[5] B Culshaw, G W Day, A D Kersey and Y Gbtsuka: "Special issue on optical fiber sensors", IEEE / OSA J. Lightware Technol., Vol.23, No.7 (1995).

[6] R M Measures, K Lin: "Fiber Optic Sensors Focus on Smart Systems", IEEE Circuits and Devices Magazine, pp.37–46 (1992).

[7] A K Ghatak, B Culshaw, V Nagarajan and B D Khurana: "Trends in Fiber Optics and Optical Communications", Viva Books (Pvt) Ltd, New Delhi (1995).

[8] D A Krohn: "Fiber Optic Sensor – Fundamental and Application", Instrument Society of India (1989).

[9] T G Gillorenzi, J A Bocara, A Dandridge and J H Cole: "Optical Fiber Sensors Challenge the Competition", IEEE Spectrum, pp.44–49 (1986).

[10] B P Pal: "Optical Fiber Sensors and Devices in Fundamentals of Fiber Optics in Tele Communication and Sensor System (1992), Wiley Eastern Ltd.

[11] T G Gillorenzi, J A Bocara, A Dandridge, G H Sigel, J H Cole, S C Rashleigh and R G Priest: "Optical Fiber Communication Technology", IEEE J Quantum Electron, Vol.2E-18, pp.625–665.

[12] A K Ghatak, K Thyagarajan: "Optical Electronics", Cambridge University Press (1991).

[13] Proceedings of conference on Optical Fiber Sensors– IEEE Conference Pub. No.221, London, April 26–28 (1983).

[14] R S Medlock: "Fiber Optic Intensity Modulated Sensors", Ed. By A N Chester, S Martelleci and A M Verge Scheggi, Martinus Nijhoff, Dordrecht (1987).

[15] G D Pitt, P Extance, R C Neat, D N Batchelder, R E Jones, J A Barnett and R H Pratt: "Optical Fiber Sensors", Proc. IEEE J. 132, pp.214–218 (1985).

[16] Proceedings of conference on Optical Fiber Sensors–2, Stuttgart, September 5–7 (1984), VDE Verlag GmgH.