# Architectural and Operational Aspects of A U Shaped Solid Glass Rod Probe Multimode Fiber Optic Analog Liquid Level Sensor

Dr. S. Venkateswara Rao
Department of Physics, JNTUH College of Engineering,
Hyderabad, Telangana, India – 500 085

***Abstract-*** **Optical fiber sensors play a crucial role in the accurate measurement of various kinds of environmental parameters with high degree of sensitivity and precision in comparison with conventional detection methods. In the present paper a multimode fiber optic U-Shaped glass rod probe evanescent wave absorption sensor is described. The experimental arrangement consists of a multimode step index plastic fiber of 200/230 µm diameter in the middle of which a sensing zone is created by connecting a solid glass rod probe which acts as core of the fiber in the sensing region. The sensor so designed is operated at a source (semiconductor laser) wavelength of 630 nm. The glass probe is then assembled vertically in a glass beaker and power is launched into the fiber from the source from one end of the sensor. Then oil is poured into the beaker by increasing the level in steps and at each stage, the level of the oil and the output power reaching the receiver connected at the other end is recorded. A linear relationship is observed between the oil column in the beaker and the output power reaching the power meter. With proper design of the sensor, the dynamic range required and maximum sensitivity can be achieved with this architecture of the sensor.**

***Keywords: Accurate measurement, U-Shaped glass rod probe, Evanescent wave absorption, Level of the oil, Linear relationship.***

## I. INTRODUCTION

The use of optical fiber in sensing applications are growing tremendously for measurement o f several chemical and physical parameters, that includes, temperature, pressure, magnetic field, acceleration, rotation, current, displacement, chemical concentration, Ph, liquid level and so forth, even though the major application has been in telecommunication. They revolutionized the sensing technology finding applications in industrial process control, automobiles, the electrical power industry, and the defense sector [1- 4]. Optical fibers can be used in hazardous environment as they are purely dielectric in nature, whereas conventionally powered sensors would not be safe. Their characteristic advantages are immune to electromagnetic interference, and have a quick response times. They can be designed into various configurations and the sensed information can be transmitted over long distances. These sensors can be configured to detect spatially distributed measurements of external parameters [5 – 7].

The measurement of sugar solution, temperature of liquid, and the estimation of iodine in iodine salt solution were reported in the literature using optical fibers [8 – 9]. An attempt is made in the present paper to construct a simple intensity modulation based liquid level sensor using a plastic optical fiber of 200/230 µm diameters of core and cladding respectively. The measurement of liquid level is one of the crucial parameters in industrial processes control of food, chemicals, oils, and petrochemicals etc. Based on various techniques such as sight glass, force – pressure, buoyancy, R. I. changes, and surface charge, a number of fiber optic liquid level sensors have been reported [8 – 16]. A multimode Plastic Clad Silica fiber with 5 mm cladding sections, separated by 5 mm striped cladding sections over the length of the fiber which constitutes the sensing zone is reported [17]. In this configuration, it can be used as an analog liquid level sensor by partially filling the beaker lengthwise and immersing the fiber sensing zone into it lengthwise. These sensors are digital in nature and used for continuous monitoring of liquid levels in the containers. By reducing the sensing zone to a bare minimum length, these sensors alternatively used as a on–off sensor for detecting the threshold level of a liquid by suspending the sensor in the liquid container so that the sensing zone coincides with the threshold level of the liquid.

In the present study, an attempt is made to design a simple U-shaped glass rod sensor for continuous monitoring of liquid level in container which facilitates to estimate the quantity of the liquid in the container at point of time. The evanescent field distributed and remote fiber optic sensing has been reported for several applications in various industrial and consumer sectors recently. The important advantage of these sensors is that the measurand can be measured from remote in real time [18-20]. During the transmission of light from a denser (core) to rarer (cladding) medium, evanescent wave enters into the rarer medium and the amplitude of the wave travelling through the denser medium gets reduced with the length of the fiber [21]. And in the rarer medium the amplitude of the evanescent wave decreases exponentially with the depth of penetration into the medium.

## II. EXPERIMENTAL ARRANGEMENT

The paper describes the geometry and working principle of a fiber optic multimode intensity U-shaped glass rod sensor which is capable of measuring the liquid level in a tank continuously from a remote place or from nearby distance based on the depth of absorption of evanescent wave into

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 11, November - 2017

the cladding when the refractive index of the liquid (oil) forms as the cladding surrounding the U-shaped glass rod which acts as a core. The schematic of the arrangement of the experiment is show in figure 1.

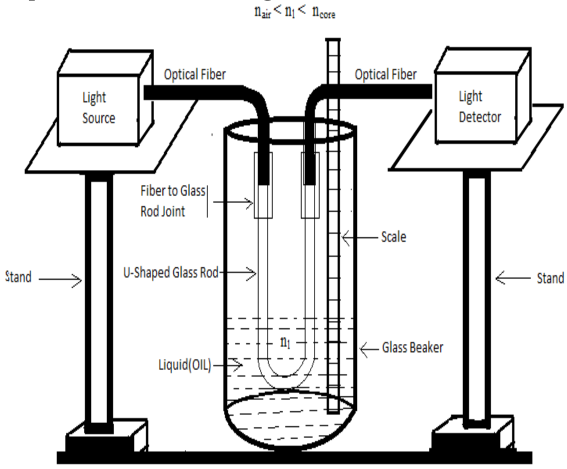


Fig. 1: Experimental Arrangement

Two plastic fibers (PCS) each of 200 / 230 µm diameters having 15 cm length, one is connected to the light source and one of the ends of the U-shaped borosilicate glass rod, and the other fiber is connected the power meter and the second end of the glass rod by using suitable connectors. This arrangement is then placed in a cylindrical glass beaker of 6 cm diameter and fixed in the beaker. A liquid proof measuring scale is vertically mounted in the beaker by fixing it to the walls of the beaker. A light source (semiconductor laser) of 630 nm is used to launch the light into the sensing system and a bench mark power meter is used to measure power entering at the receiver end of the sensor by properly placing them on the stands at a fixed height.

Light is launched from the semiconductor laser source into the input end of the fiber which is guided through fiber via the U-shaped glass rod and emerges through the other fiber connected at the other end and couples into the power meter connected at the receiving end. The variation in the intensity of guided light is recorded in the power meter as the liquid level in the beaker increase. The intensity of the light in the power meter varies in accordance with the change in the liquid level in the container as the power reaching the power meter is a function the length (height) of the liquid column in the sensing zone (U-shaped glass rod) of sensor system in the container. The depth of absorption evanescent field into the liquid increases with the increase the level of liquid in the sensing zone thereby the power reaching into the power meter decreases. This scheme of sensing is highly useful in the measurement of oil in oil tank, petrol in a petrol tank or water in a water tank simply placing the source and the power meter on a desk top at a remote place or at any convenient place nearby.

## III. RESULTS AND DISCUSSION

In the present sensor a borosilicate glass solid rod is bent in the form of U used in the sensing zone, which acts as core of the fiber in that region and the liquid surrounding the rod acts as a cladding to measure the liquid level of in the container. The U-bent glass rod, when immersed in a liquid of refractive index $n_l$ ( > $n_{air}$) yields a signal that is different from the signal that in an unbent glass rod. The variation of the power loss (attenuation) increases linearly with the length of the liquid cladding and in other words, the power transmitted through the fiber will decrease linearly with increasing the in the $n_l$ of the liquid surrounding the glass rod as per the equation given.

$$P = P_0 \frac{n_1^2 - n_l^2}{(n_1^2 - n_{cl}^2)}$$

It is evident from this equation that power coupled to output fiber through the U-shaped glass rod increases linearly with proportional decrease in $n_l^2$. Immersing the U-shaped glass rod in a number of liquids with various indices of refraction and monitoring the corresponding power reaching the power meter at the receiving end, the calibration curve is generated [Fig. 2]

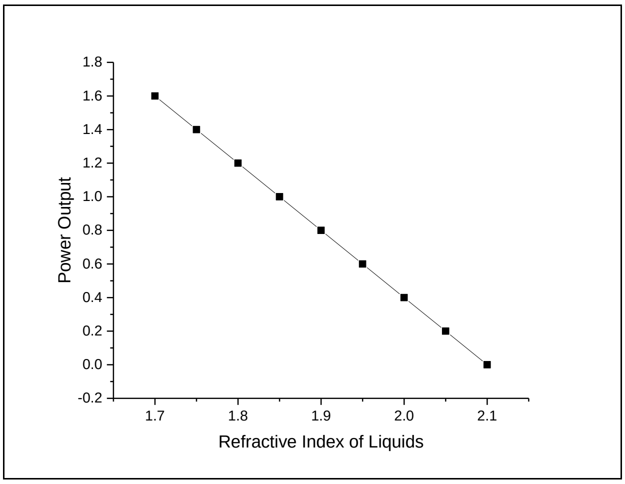


Fig. 2: Variation of power $P_n$ with refractive index liquid cladding, $n_l^2$.

Thus by measuring the power exiting the from output fiber when U-shaped glass rod immersed in a liquid of unknown refractive index, the calibration curve can be used to determine the refractive index of unknown liquid.

The variation of normalized power $P_N = (1/P)(dP/dn_l)$ with refractive index of various liquids is depicted in the fig. 2. From the fig. 2 it is noticed that the output power exhibited the exponential variation with refractive index of the liquid. However, the sensitivity

$$\alpha = \left( dP / dn_l \right)$$

is more around 1.45 which value is near to the refractive of the borosilicate glass rod (R.I. = 1.45). The increase in sensitivity is attributed to the evanescent wave absorption due to the penetration depth of the evanescent field into the liquid cladding due to the increase in refractive index of the liquid.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 11, November - 2017

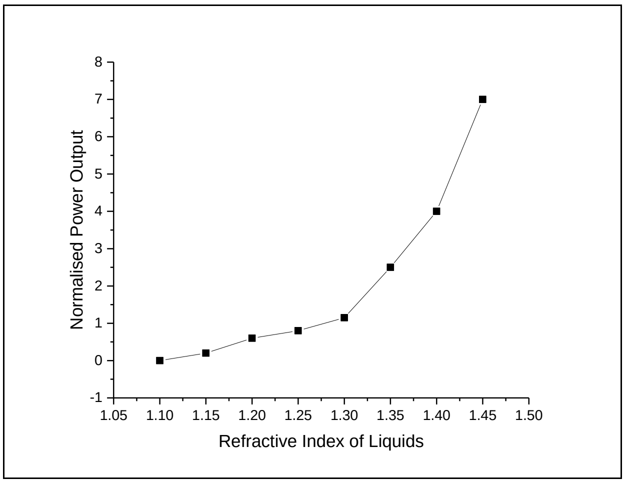


Fig. 3: Variation of Normalized Power output,

$P_N = (1/P)(dP/dn_l)$ with Refractive index of various Liquids, $n_l$

Now a single liquid is chosen whose refractive index is specified fixed (oil of R. I. = 1.426) which is less than the U-shaped glass rod core (R. I. =1.5), used to study the variation of power by varying the length of liquid column around the core. In this case it is observe that the absorption and hence the sensitivity is increased as penetration depth of the field and the results are plotted in the fig. 3. The performance of the oil level fiber optic intensity based sensor so developed is studied by choosing specific parameters for both liquid and the dimensions of the glass container. But irrespective of the dimensions of the liquid and container, the variation of the optical power with the height of the liquid column surrounding the U-shaped glass sensor is universal with decrease in output power values in accordance with increase in level of the liquid surrounding the glass rod in the sensing zone. The parameters chosen are tabulated in table 1, for effective measurement of liquid levels using the present sensor. The heights of the liquid are measured in centimeters and the volumes of the liquid are measured in milliliters (ml).

Table 1: Volume of oil in liters, V (L), and the corresponding heights H (in cm), inside the container.

| Parameter | Oil level multimode fiber optic intensity based U-shaped solid glass rod performance | | | | | |
|---|---|---|---|---|---|---|
| V(ml) | 0.0 | 10 | 20 | 30 | 40 | 50 |
| H (cm) | 0.0 | 1.2 | 1.9 | 2.6 | 3.4 | 4.3 |
| OL= Oil Level | OL = 0 | 10 > FL > 0 | 20 > FL > 10 | 30 > FL > 20 | 40 > FL > 50 | 60 > FL > 50 |

By reducing the sensing zone, i. e. the U-shaped glass rod (the sensing region), to a bare minimum length, this sensing configuration can be alternatively used as a on-off sensor for determining the threshold level of a liquid by suspending the sensor in the liquid container so that the sensing coincides with the threshold level. This way it can be used to trigger an alarm signal if a hazardous liquid like petrochemical is found to ever cross the danger level in its storage tank.

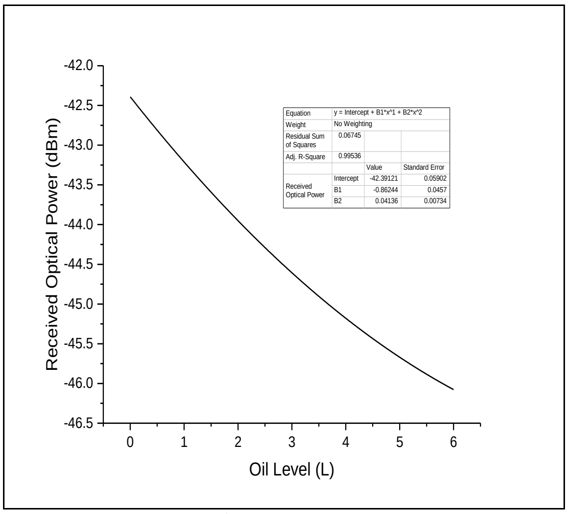


Fig. 4: Variation of Output Power with Liquid level

The liquid level U-shaped glass rod sensor also can be designed by stripping the cladding over the entire length of the fiber, but this is useful over a short range as the power absorption by air would be large. Moreover, the calibration of liquid level with power would become complicated. To avoid this difficulty, it is suggested that the use of a multimode PCS fiber with 5 mm sections of cladding, striped off apart over the length of the fiber. In this method when the liquid is anywhere in between the 5 mm section containing the cladding, the liquid contained at that position cannot be determined precisely and the calibration of liquid level with power becomes difficult.

## IV. CONCLUSIONS

By choosing the power requirements and length of the unclad region, the proposed liquid level sensor can be designed easily for several liquid level tanks. This configuration can also be exploited in the leak detection of various liquids and to upgrade sensors for other physical parameters by modulating the length of the unclad portion in accordance with the magnitude of that particular parameter. The so developed can be employed for the continuous measurement and monitoring of liquid levels in wide range of industries and other fields.

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