International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 09 , September 2017
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Calibration and Development of a Novel Multimode Fiberoptic U – Shaped Solid Glass Rod Based Sensing Probe to Measure Refractive Index of Various Transparent Liquids

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ABSTRACT

Most of the properties of the substances either in liquid state or solid state are critically characterized by a single parameter i.e. Refractive Index. The study of Refractive Index of many chemicals, oils of several plants, fragrant oils and bio fluids are very impartment to scientist, chemist and researchers. Several methods have been developed to study the Refractive Index of liquids as mentioned in literature. In the present paper it is proposed to study a robust, chemically inert and cost effective U – shaped solid glass rod based sensing probe for the study of Refractive Index of various liquids. In the assessment of the sensor it is crucial to calibrate the sensing probe and to develop thesensing system that includes sensing probe. Various binary chemical mixtures have been used in the calibration of the sensor such as methanol mixed in benzene, propanol mixed in benzene, butanol mixed in benzene and cyclo-hexane missed in benzene. The dynamic range of the sensors so developed was ranging from 1.3 $n_D$to 1.5 $n_D$by using sodium lamp as the light source.

Keywords –Bio fluids, Calibration, Chemicals,Dynamic range, Refractive Index, Sensing Probe, U – Shaped solid glass rod.

I. INTRODUCTION

It is reported in the literature that a highly transparent glass can be used as sensing element in the extrinsic fiber optic sensor. The quality of the fiber is decided by the transparency which in turn depends on the purity of the glass to prepare the fiber. Several sensors developed in the resent past have made use of optical fibers fabricated from high quality glasses [1, 2]. The sensor converts one form of environmental parameter into other form of parameter which can be measured more conveniently with comfort when they are properly designed. In this process the non-optical perturbation on a glass probe will be converted into an optical signal. Even though several fiber optics sensors can be realized i.e. intensity modulated fiber optic sensors, interferometric fiber optic sensors, phase modulated fiber optic sensors and wavelength modulated fiber optic sensors, the intensity modulated FO sensors occupy the major part of the fiber optic sensors [3-5]. Innumerableenvironmentalparameters can be measured simultaneously or one after the other with the help glass rod based sensors with highest degree of sensitivity due to their flexibility in the usage. In the present study a novel method to study the Refractive Index of various liquids is proposed to develop a sensitive and portable

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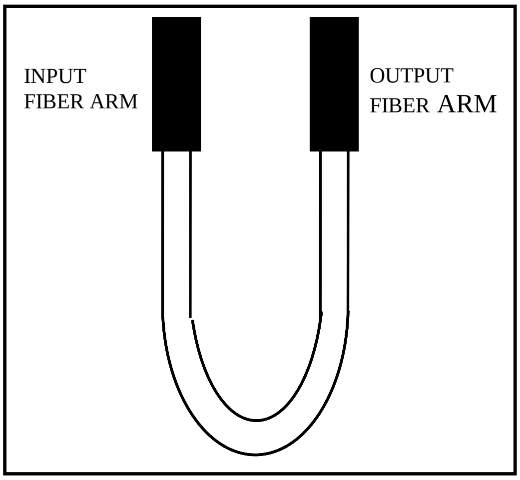
sensor for measuring the properties of various liquids the Refractive Index of which will lie in the range of 1.3 – 1.5.

II. EXPERIMENTAL ARRANGEMENT

The use of U – shaped solid glass rod as a sensing probe in the experimental arrangement has been mentioned elsewhere [6-7]. A U – shaped glass rod prepared from borosilicate glass was used in the present work as sensing element[8-9] [Fig.1].The geometrical parameters of the glass rod used in the experimentation have been depicted in figures [Fig.2].



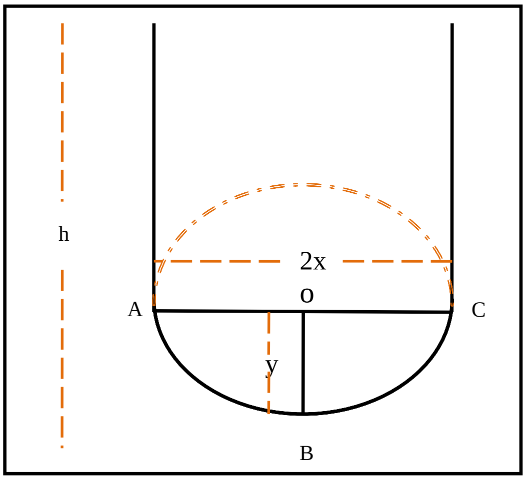


Fig.1: U- shaped glass rod **Fig.2: Geometrical parameters of U- shaped glass rod.**

Geometrical parameters:

Thickness (diameter) of the glass rod : 0.2mm

Height of the glass rod (h): 4cm

Width between the two prongs (2x): 1cm

Depth of the curvature (y) = x, radius of the curvature: 0.5cm

Light from a semiconductor LASER diode is launched into the input arm of a plastic core silica fiber (PCS) which in turn is connected to one end of the U – shaped glass rod, and the light emitted from other end of the glass rod is being coupled to output arm of the plastic core silica fiber (PCS) which is connected to a power meter. In the experiment a 62.5/125µm plastic core silica fiber (PCS) having the dimensions as that of glass rod that bent in a shape of U were used. At each coupling point i.e. coupling of fiber to glass rod and fiber to the terminal equipment, enough care is taken that no light escapes out at the joint. Index matching glue that is available in the local market is used for proper sealing and which was covered with M-Seal and insulation tape for additional precaution at each end of U – shaped rod.A suitable connector is used at the point of launching the light from source into the input fiber arm. A similar care was taken in connecting the output fiber arm to the power meter. Thus the experimental arrangement is made ready for the experimentation to be carried out[Fig-3].Suitable stands were used to place both light source and light detector in the arrangement. A transparent glass container has been used to maintain the uniform measurand environment surrounding the U – shaped glass rod.

IJARSE
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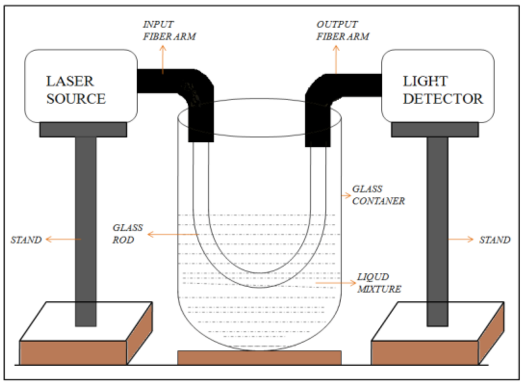
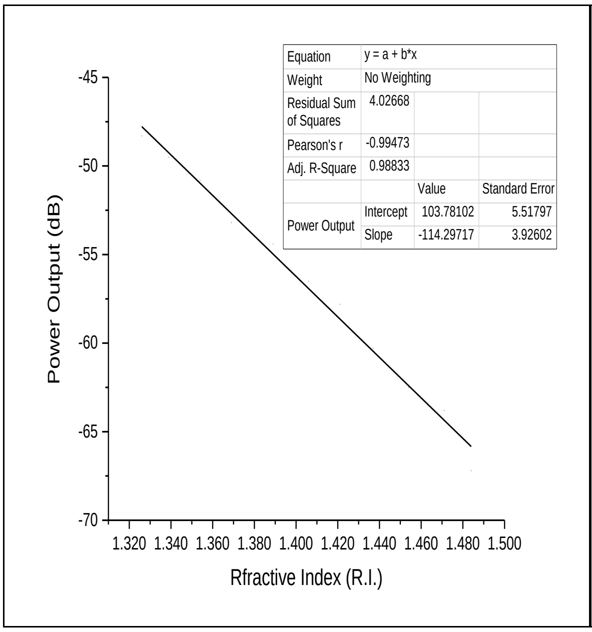


Fig.3: Experimental arrangement of glass sensor

III. EXPERIMENTAL DETAILS

Initially the binary mixture of methanol and benzene of various volumes making the total volume of the mixture always at 10ml is poured into the wide mouth beaker immersing the U- shaped glass rod into it. Light is lunched into the input fiber arm and collected through output fiber arm which travels via U- shaped glass rod. As some amount of the light enters into the liquid, due to the absorbing property of the liquid sounding the U- shaped glass probe, the light collected at the output end will be decreased. The Refractive Index of mixture at each time is measured using Abbes Refractometer. The R.I. value and power at the output end are noted in the tabular form. The experiment is repeated for various mixture of methanol mixed in benzene having different R.I. values. It is noticed that as mole fraction of the methanol in benzene increases the power output also increases as expected. At the same time it is observed that as R.I. value of binary mixtures decreases, the power output increases. The experiment was repeated by taking the mixture of propanol mixed in benzene, butanol mixed in benzene and cyclo-hexane mixed in benzene. The results are represented graphically in Figs.4-7.



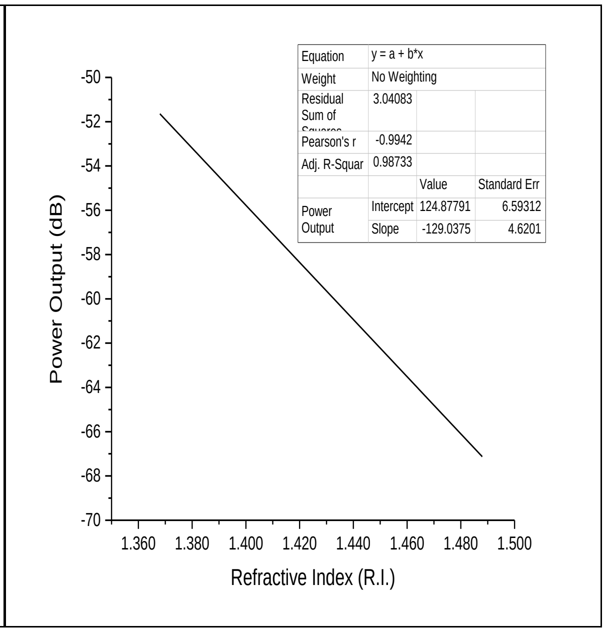


Fig.4: Methanol and Benzene mixtureFig.5: Propanol and Benzene mixture

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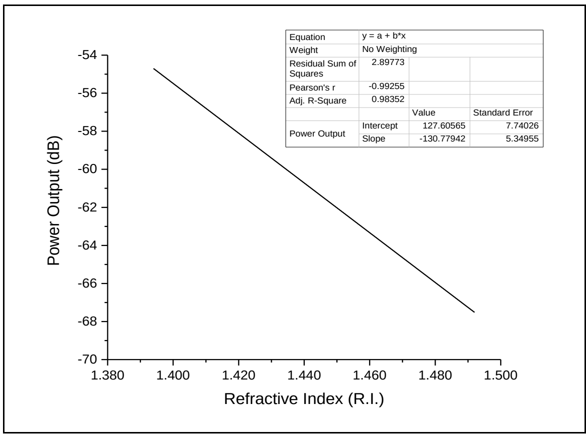

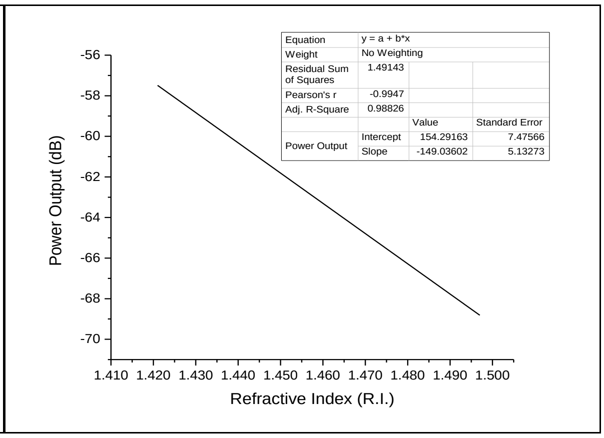

Fig.6: Butanol and BenzenemixtureFig.7:Cyclohexane and Benzenemixture

IV. CALIBRATION

For the calibration of the U- shaped solid glass rod as a sensing element to measure various transparent liquids, mixtures like methanol mixed with benzene, propanol mixed with benzene, butanol mixed with benzene and cyclo-hexane mixed with benzene were consider to have a dynamic (operational) range from 1.3 $n_D$to 1.5 $n_{D.}$ As explained earlier, different proportions of each combination were surrounded the U- shaped probe and each time the power output was noted in the optical power meter. With the combination of methanol mixed with benzene the dynamic range of R.I values (1.33-1.50) were recorded by using Abbes' Refractometer. The corresponding power was noted in the optical power meter. This was repeated by using combinations of other mixtures. In case of propanol mixed with benzene the dynamic range of R.I values (1.38-1.50), for butanol mixed with benzene the dynamic range of R.I values extended from 1.40-1.50. Similarly in case of cyclo-hexane mixed with benzene the dynamic range of R.I values lies between 1.42-1.50.

The overall dynamic range of R.I values with all combinations lie between 1.3-1.5.The unified graph with all the mixtures for Refractive index and power is represented in fig-8. The unified graph drawn represents, the output power values corresponding to the respective R.I. values. Each power value on the Y-axis corresponds to aparticular value of R.I. on X-axis. Thus by knowing the power value when some unknown liquid surrounding the U- shaped sensing probe, the corresponding Refractive Index can be found on the Y-axis from the standard graph drawn. Hence the Refractive Index of an unknown transparent liquid whose range lies between 1.3-1.5 can be determined using the sensor developed in the present work.

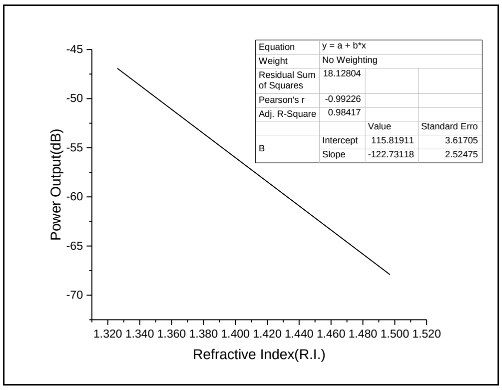

Fig. 8: Unified Standard graph

IJARSE
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(Methanol + Benzene, Propanol + Benzene,

Butanol + Benzene, Cyclohexane + Benzene)

V. CONCLUSION

The intensity of the light collected at the output end is maximum when the sensing probe is surrounded by the air (R.I.-1.0) as most of the light is confined to the medium (R.I.-1.5) i.e. within sensor. The light is no longer remind in the sensor and some part of it starts escaping into the surrounding medium when the probe is dipped in a medium of higher Refractive Index than that of air, and this leads to a reduction in the power sensed at the receiver end. As the present developed glass sensor is immune to chemical reaction will be of immense use for instant check of R.I. of several transparent liquids and their mixtures whose r. irange between 1.3 and 1.5.

VI. ACKNOWLEDGEMENT

The authors are grateful to Prof. Md. Adeel Ahmad, Prof. of Physics(Rtd.), NizamCollege (Autonomous) Osmania University, Hyderabad for the help rendered in the preparation of the manuscript,and the support extended to choose and carryout the research work in the area of fiber optics.

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