A Novel Extrinsic Intensity Modulated Fiber Optic Chemical Sensor Based on U-Shaped Glass Rod – Study of Properties of Propanol mixed in Benzene and Cyclo-hexane mixed in Benzene

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ABSTRACT:

An optical fiber chemical sensor for the detection of refractive index of Propanol mixed in Benzene and Cyclo-hexane mixed in Benzene based on an extrinsic U-bend probe is reported in the present work. Two PCS fibers of 200/230μm of 50cm length in which one as input fiber arm and other as output fiber arm are used in the experimental setup operated at 630nm. The sensing region is created by joining the one end of the U-shaped glass rod to input fiber arm and the other end of the glass rod to the output fiber arm. The other end of the input fiber arm is connected to a LASER source of 630nm while the other end of the output fiber arm is connected to a power meter. The U-shaped glass rod which acts as extrinsic sensing probe is slowly placed in the liquid mixtures. The bending of sensing region enhances the sensitivity of the device of the order of 10^{-3} in measuring the refractive indices of chemical mixtures of different mixed ratios. As the chemical mixtures of different mixed ratios with increasing Benzene quantity introduced into the sensing region a sharp decrease in the output intensities observed in the power meter. The variation in the intensity can be correlated to the increase in the refractive index of the chemical mixtures exposed to the sensing zone. The sensors so developed may be directly employed in various applications such as chemical industry, polymer industry, electronic industry, pharmaceuticals, agriculture etc. The proposed sensor is portable, inexpensive, easy to fabricate and can be used to measure the refractive index of chemicals from remote.

Keywords: *Chemical mixtures, Cyclo-hexane mixed in Benzene, PCS fibers, Propanol mixed in Benzene, Refractive index, Sensitivity, U-bend probe.*

I. INTRODUCTION

An intensive research work has been taken up throughout the world in the area of chemical fiber optic sensors during last few decades [1-8]. The sensors are used in the chemical process for the continuous mentoring of reactant concentration and also in the determination of liquid absorption spectra. The working principle of sensor bases on the attenuated total internal reflection (ATR) spectroscope. In which the cladding of an optical fiber is removed from a small region of fiber which form the sensing region of the fiber. The sensing zone so formed is immersed in an absorbing fluid. Light from a source at one end is launched into the fiber and is collected by other end of the fiber using light detector. The amount of output power depends upon the loss caused by the fluid surrounding the core due to the difference in the refractive index of fiber core and substance surrounding the core of the fiber. Selective rays launching from fiber core and deforming techniques can be use to increases the sensitivity of the exposed core of the fiber. Only rays of incident angles which are closed to the critical angle are injected into the fiber in the case of selective ray launching [1]. The most famous forms of fiber core deformation are tapped cores of the fiber [2, 3] and U-shaped bend core of the fiber [4]. The U-shaped bend core fibers have been used as the refractive index sensors to measure the refractive index of various liquids [5] and in pattern recognition of artificial neural network with distributed sensing [6-10].

There is an argent requirement for sensors for an exact control of the concentrations for better performance of the fuel cells. Propanol and Cyclo-hexane are important chemicals for industrial use in a void range from feedstock to antifreeze. Numerous optical sensing methods utilizing various absorption spectroscopic lines have been reported in the literature [11-14]. A comparison to a straight exposed fiber core and a U-bend fiber core with reference to core diameter, the numerical aperture (NA), the radii of bend and index of refraction of surrounding fluid in terms of sensitivity have been reported in the literature [15-17]. A step-index multimode fiber has been used to describe the sensitivity of a single U-bend probe in the above approach.

II. EXPERIMENTAL ARRANGEMENT

The basic elements of experimental arrangement consist of a LASER diode light source of 630nm, a bench mark power detector and an extrinsic intensity modulated fiber optic (200/230μm) sensing system where in a U-shaped borosilicate glass rod of thickness 0.20mm was used as a sensing probe. The chemical samples for investigation of refractive index in the range between 1.37n_D to 1.49n_D have been prepared by using a burette system by taking different proportion of Propanal mixed in Benzene and Cylco-hexane mixed in Benzene. To calibrate the U-shaped glass sensor initially the refractive indices of all the chemical mixtures were determine by using Abbe's refractometer aided with sodium vapour lamp. The experimental setup as shown in fig. [1].

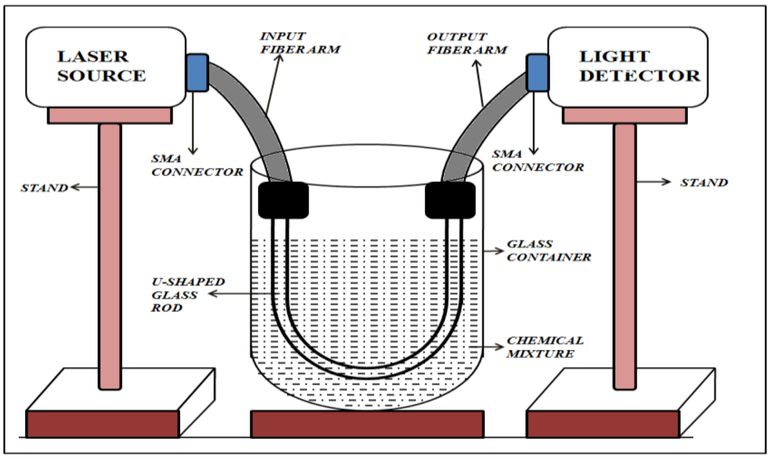

Fig-1: Experimental arrangement of Fiber Optic Chemical Sensor Based on U-shaped Glass Rod

Fiber Optic Chemical Sensor Specifications

- Fiber patch card: 200/230µm
- Length of the fiber patch card with SMA connector: 50cm
- Length of the SMA connector: 5cm
- Shape of the glass rod: U- shaped solid glass rod
- Thickness of the glass rod:0.2mm
- Total height of the glass rod: 3.0cm
- Height of the glass rod immersed in the liquid: 2.0cm
- Width between the two Prongs of the U-shaped glass rod: 1.5cm
- Depth of the curvature (Radius of the curvature): 1cm

III. RESULTS AND DISCUSSION

The light launched from LASER source transmits through the input fiber arm which acts as optical wave guide and enters into U-shaped glass sensing probe and transmits from sensing probe to power detector. A correlation can be formulated between light that is coupled to the power meter and light that is lossed at sensing region. By using different chemical mixtures surrounding the sensing probe light launched from the source and light received at the detector was observed and the readings were tabulated. Initially the chemical mixture Propanol mixed in Benzene with different proportions were used in the experimentation and the readings are tabulated in table-1.

Table-1: Molefraction of Benzene & Propanol in Benzene + Propanol mixtures and Refractive Index, Output Power(dBm), Density(g/ml), Molar Volume(c.c./mole), Molar Refraction (c.c./mole), d(R.I.)/R.I. of glass rod of Benzene + Propanol chemical mixtures.

S. No.	Volume of the binary mixtures (ml)		Molefraction		Refractive Index	Output Power (dBm)	Density (g/ml)	Molar Volume (c.c./mole)	Molar Refraction (c.c./mole)	d(R.I.)/R.I. of glass rod
	Benzene	Propanol	Benzene	Propanol						
1	10	0	1.0000	0.0000	1.488	.73	0.8765	89.1158	25.6753	0.0080
2	9	1	0.9147	0.0853	1.471	.07	0.8692	88.0958	24.3541	0.0193
3	8	2	0.8265	0.1735	1.460	.10	0.8618	87.0080	23.8305	0.0267
4	7	3	0.7354	0.2646	1.453	.37	0.8544	85.8402	23.2015	0.0313
5	6	4	0.6411	0.3589	1.440	.10	0.8471	84.5740	22.2895	0.0400
6	5	5	0.5436	0.4564	1.430	.30	0.8398	83.2170	21.6400	0.0467
7	4	6	0.4426	0.5574	1.416	.23	0.8324	81.7704	20.5200	0.0560
8	3	7	0.3379	0.6621	1.409	.53	0.8251	80.2072	19.8296	0.0607
9	2	8	0.2294	0.7706	1.395	.40	0.8177	78.5420	18.8300	0.0700

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10	1	9	0.1168	0.8832	1.383	.53	0.8104	76.7457	17.9020	0.0780
11	0	10	0.0000	1.0000	1.372	.90	0.8030	74.8319	17.0077	0.0853

The other properties like density, molefraction, molar volume, molar refraction, d(R.I.)/R.I. of glass rod also correlated with output power. The variation in optical power with respect to concentration and the refractive index have been represented in fig. [2-8].

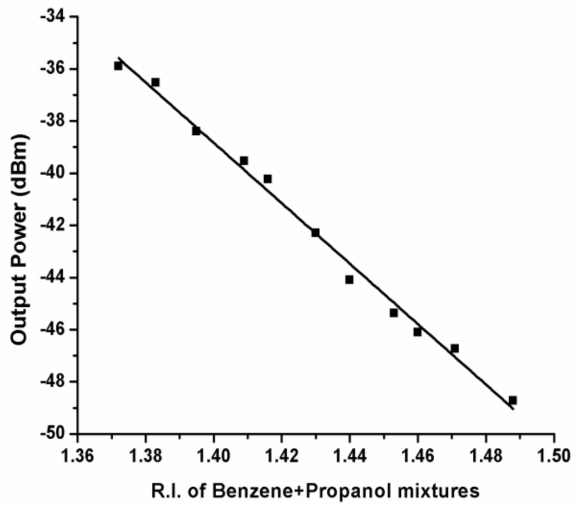


Fig-2: Relation between Refractive Index of Benzene+Propanol mixtures Vs Output Power(dBm)

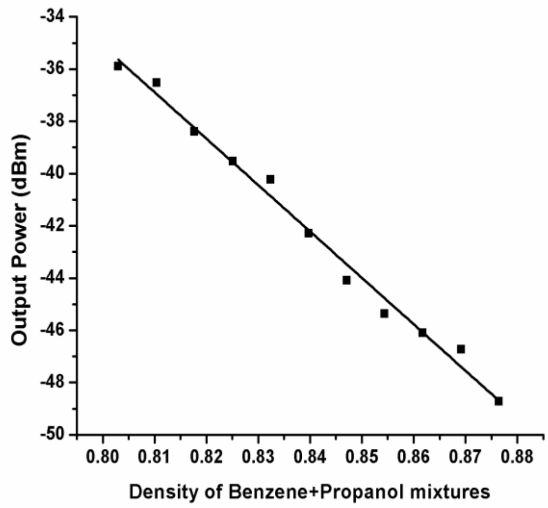


Fig-3: Relation between Density(g/ml) of Benzene+Propanol mixtures (g/ml) Vs Output Power(dBm)

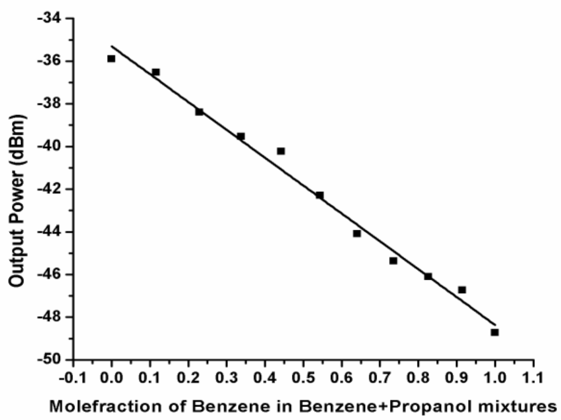


Fig-4: Relation between Molefaction of Benzene in Benzene+Propanol mixtures Vs Output Power(dBm)

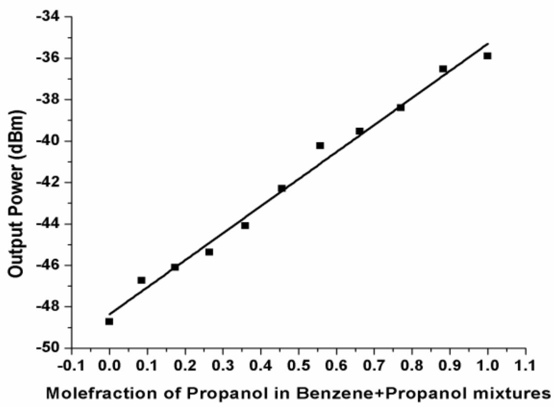
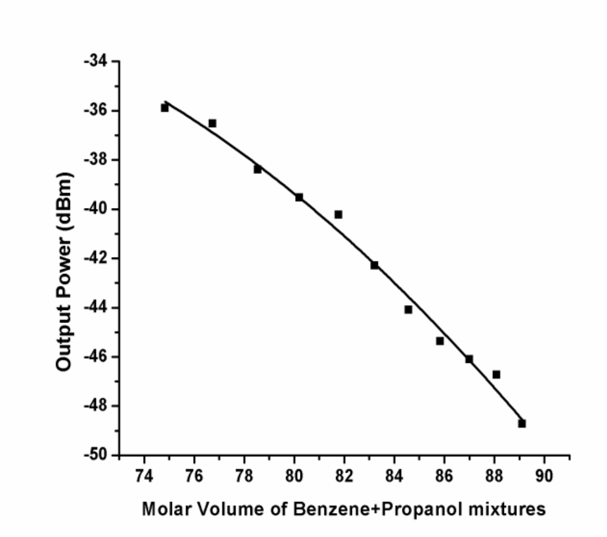


Fig-5: Relation between Molefaction of Propanol in Benzene+Propanol mixtures Vs Output Power(dBm)



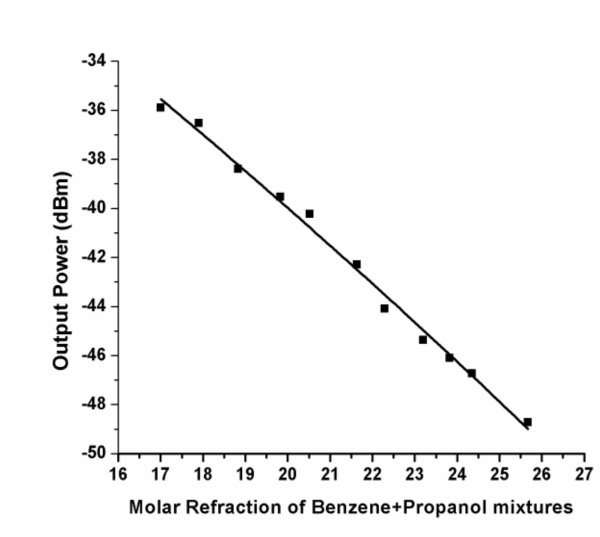


Fig-6: Relation between Molar Volume(c.c/mole) of Benzene+Propanol mixtures Vs Output Power(dBm)

Fig-7: Relation between Molar Refraction (c.c/mole) of Benzene+ Propanol mixtures Vs Output Power(dBm)

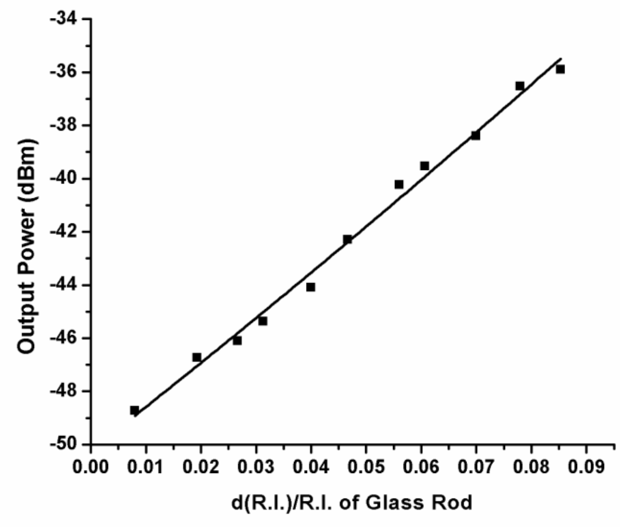


Fig-8: Relation between d(R.I.)/R.I. of Glass Rod Vs Output Power(dBm)

From the fig.2 the refractive index of chemical mixture increases the output power decreases. The decrement in the output power attributed to the absorption of light by the chemical mixture surrounding the U-shaped glass rod which is acting as a liquid cladding of the optical transmission system. The depth of the absorption of light increases as the R.I. of chemical cladding increases. When more light absorbed at sensing region due to the increment in the R.I. of liquid less power will reaches as output of the sensors. In conforming the experimental

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observations made with Propanol and Benzene another combination of chemicals i.e. Cyclo-hexane mixed in Benzene was used as liquid surrounding the U-shaped glass probe and results are tabulated in table-2.

Table-2: Molefractions of Benzene & Cyclo-hexane in Benzene + Cyclo-hexane mixtures and Refractive Index, Output Power(dBm), Density(g/ml), Molar Volume(c.c./mole), Molar Refraction (c.c./mole), d(R.I.)/R.I. of glass rod of Benzene + Cyclo-hexane chemical mixtures.

S. No.	Volume of the binary mixtures (ml)		Molefraction		Refractive Index	Output Power (dBm)	Density (g/ml)	Molar Volume (c.c./mole)	Molar Refraction (c.c./mole)	d(R.I.)/R.I. of glass rod
	Benzene	Cyclo-hexane	Benzene	Cyclo-hexane						
1	10	0	1.0000	0.0000	1.488	.73	0.8765	89.1158	25.6753	0.0080
2	9	1	0.8812	0.1188	1.478	.87	0.8667	90.9527	25.7456	0.0147
3	8	2	0.7672	0.2328	1.469	.90	0.8568	92.8086	25.7992	0.0207
4	7	3	0.6578	0.3422	1.462	.43	0.8470	94.6639	26.0245	0.0253
5	6	4	0.5527	0.4473	1.459	.90	0.8371	96.5430	26.3925	0.0273
6	5	5	0.4517	0.5483	1.453	.37	0.8273	98.4252	26.6031	0.0313
7	4	6	0.3545	0.6455	1.447	.80	0.8175	100.3245	26.8053	0.0353
8	3	7	0.2700	0.7300	1.439	.83	0.8076	102.1873	26.8783	0.0407
9	2	8	0.1708	0.8292	1.433	.67	0.7978	104.1949	27.0799	0.0447
10	1	9	0.0839	0.9161	1.425	.77	0.7879	106.1713	27.1478	0.0500
11	0	10	0.0000	1.0000	1.420	.90	0.7781	108.1609	27.3715	0.0533

Graphs are plotted by taking various parameters of the chemical compounds with respect to output power of sensor system and the results are analyzed in fig. [9-15]. Similar variations are observed as results obtained in the case of Proponal mixed in Benzene.

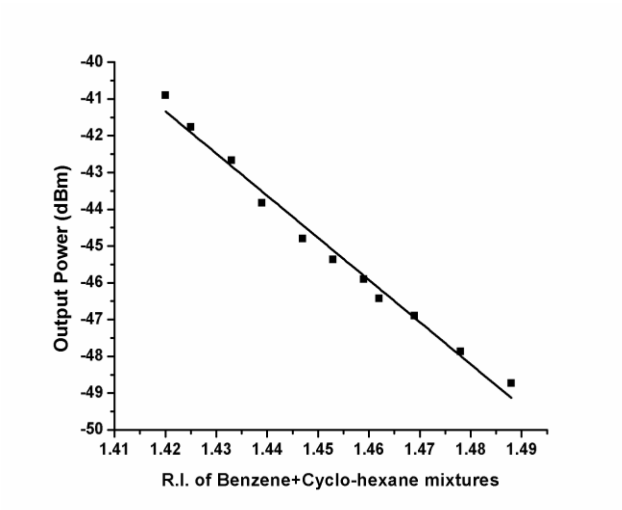

Fig-9: Relation between Refractive Index of Benzene+Cyclo-hexane mixtures Vs Output Power(dBm).

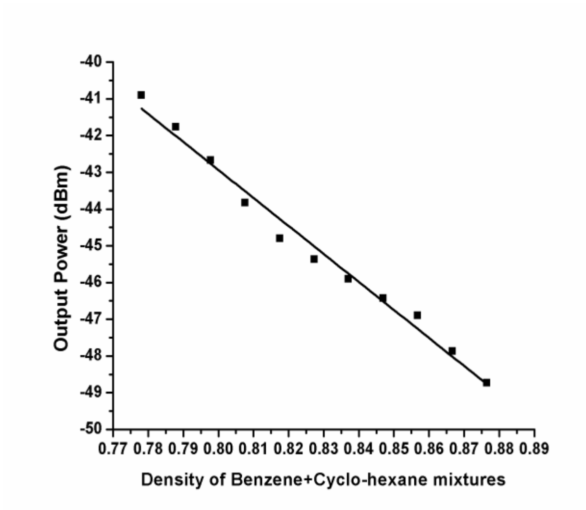

Fig-10: Relation between Density (g/ml) of Benzene+Cyclo-hexane mixtures Vs Output Power(dBm).

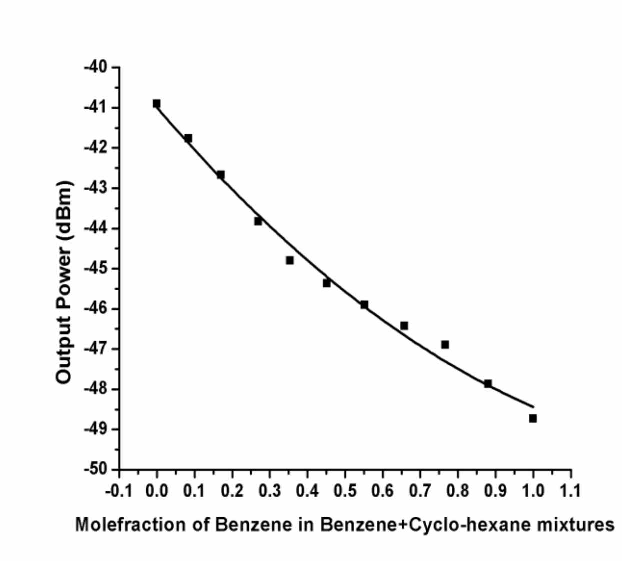

Fig-11: Relation between Molefraction of Benzene in Benzene+Cyclo-hexane mixtures Vs Output Power(dBm).

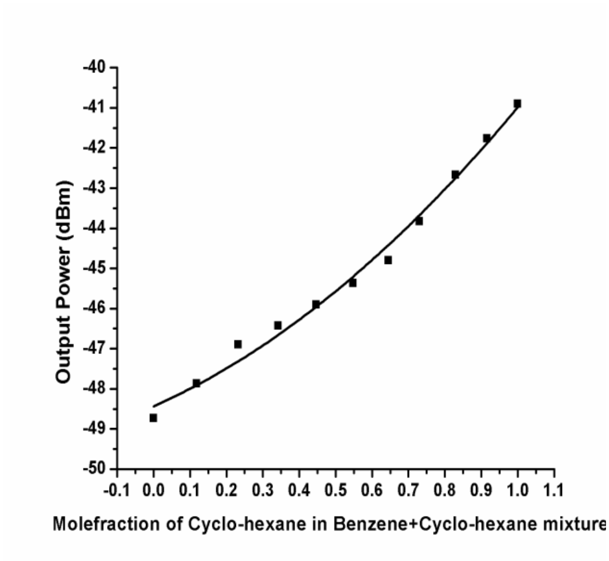

Fig-12: Relation between Molefraction of Cyclo-hexane in Benzene+Cyclo-hexane mixtures Vs Output Power(dBm).

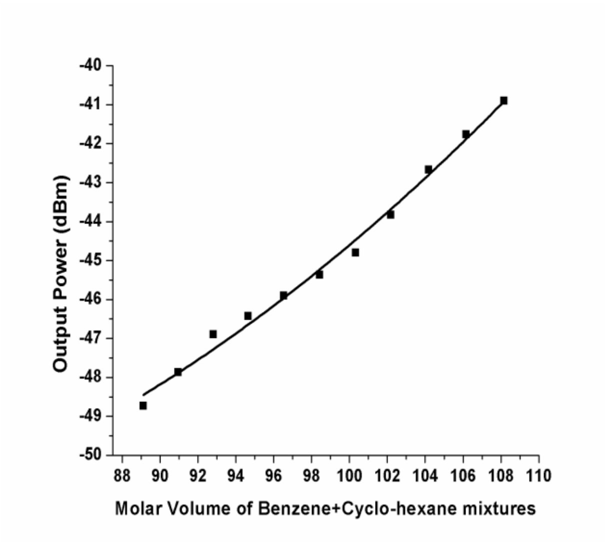

Fig-13: Relation between Molar Volume (c.c./mole) of Benzene+Cyclo-hexane mixtures Vs Output Power(dBm).

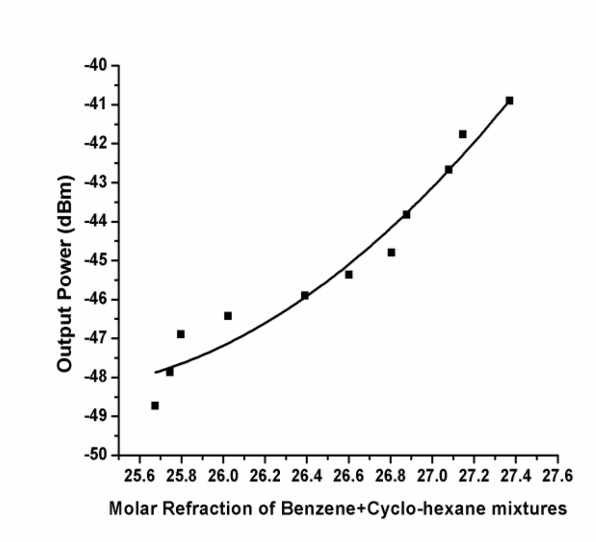

Fig-14: Relation between Molar Refraction (c.c./mole) of Benzene + Cyclo-hexane mixtures Vs Output Power(dBm)

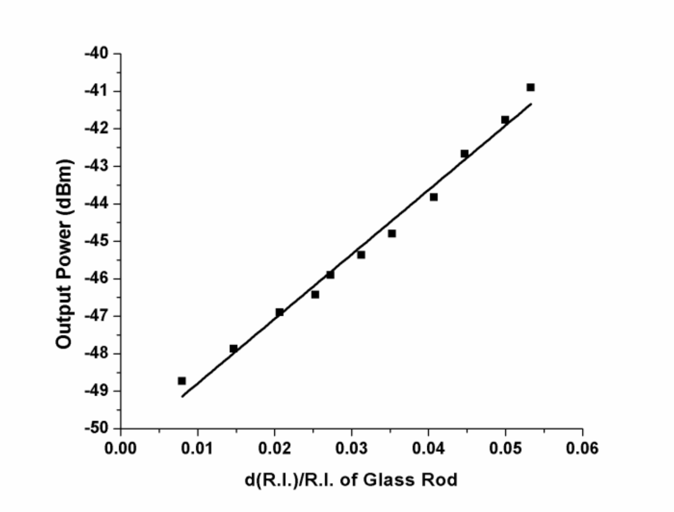

Fig-15: Relation between d(R.I.)/R.I. of Glass Rod Vs Output Power(dBm).

Calibration: Calibration is one of the crucial aspect in designing a sensor or detector. Making the marks with qualitative change in the measurer quantity corresponding to the change in the measurand quantity is called calibration. In the present work the calibration is done by taking the power as a measurer quantity and refractive index as a measurand quantity and the standard graph is plotted for a dynamic range 1.37n_D to 1.49n_D by plotting various power with refractive indices of Propanol mixed in Benzene and Cyclo-hexane mixed in Benzene as shown in fig. [16].

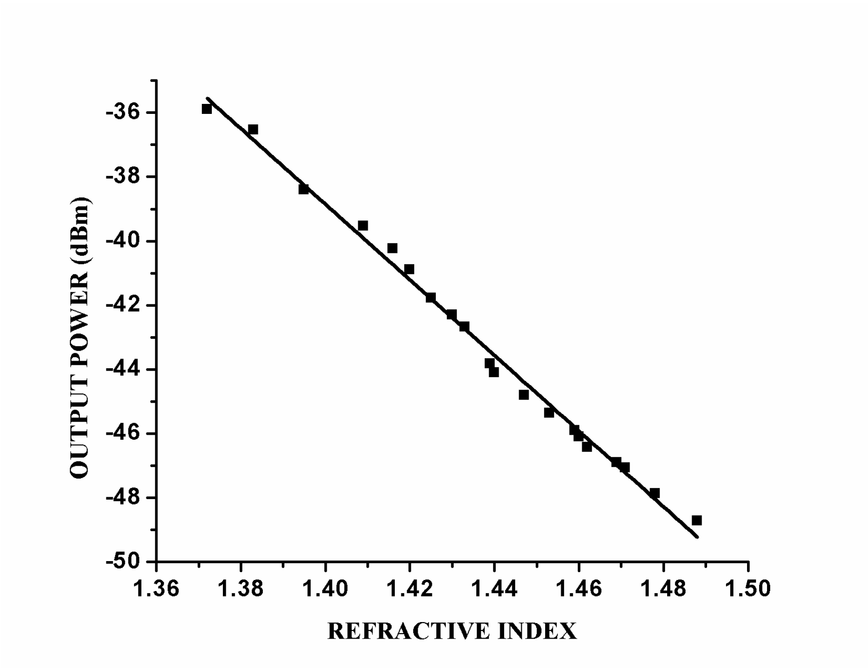

Fig-16: Relation between Refractive Index Vs Output Power(dBm) of Benzene+ Propanol and Benzene + Cyclo-hexane mixtures.

IV. CONCLUSION

In the present work the variation of output power with the refractive index of the transparent liquids whose dynamic range lies between $1.37n_D$ to $1.49n_D$ at room temperature were investigated and the standard graph was plotted. With the help of standard graph the refractive index of unknown transparent liquids can be determine whose range lies between $1.37n_D$ to $1.49n_D$.

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