4.1 INTRODUCTION:

This chapter is an extended work of chapter III, which presents an innovative technique for determining the refractive indices of liquid and air. To the best of our knowledge, Zernike Three Beam Interferometer has been used for the first time for evaluating the Refractive index of air and liquid. The liquid immersion method Kasana & Rosenbruch [1-3] has been adopted for this purpose. The proposed method needs a pair of liquid/ medium at a time. The lens L_2 is immersed in the liquid inside a glass cell which is placed on the optical bench in such a way that the parallel light insides the glass cell containing the test liquid or air. This parallel light after passing through the lens L_2 and test liquid or air, produce an interference pattern consisting of equal-spaced, parallel straight fringes to back focal plane of lens L_2.

The three beam Zernike's Interferometer is easy to set up and is very stable (4). The three beams are produced by amplitude division and produce an interference pattern consisting of equal-spaced, parallel straight fringes. The liquid immersion technique for determining the liquid index is widely known. These existing factors do not take into account the effect of the lens aperture, aberration, thickness of the glass cell.

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1. R.S. Kasana and **Arvind Kumar Deshmukh**, "Refractometry of liquid by using liquid immersion and three beam interferometric techniques", *International Journal of Pure and Applied Physics*, 6(3), 263-268 (2010).

2. R.S. Kasana and **Arvind Kumar Deshmukh**, "Refractometry of air with liquid immersion method", *Atti Della "Fondazione Giorgio Ronchi"*, Vol.Anno LXV(N-4),2010 (Accepted).

Earlier worker's have used a mixture of liquid for matching the value of lens index with refractive index of liquid mixture thus this value of liquid mixture is just equal with the lens index. To eliminate such difficulties Smith (5) has come forward by using only one liquid at a time. However, his approach was recursive in nature and associated with various instrumentation components *R. S.* Kasana and Rosenbruch (6) have reported a new focussing non-miscible liquid immersion technique. Richerzhagen (7) has described a simple method for measuring the absolute refractive index of liquid as a function of temperature with Michelson interferometer. Several Scientists have centered their attention on discovering practical techniques for finding the refractive index of liquid and gases (8-43) and glass samples in the form of lens. Many attempts have been make from time to time which have been reported in literature.

We have centered our attention for the study the interferometric refractometry of liquids or air. In present chapter for this purpose an innovative approach has been exercised to establish a relation between the refractive indices of liquids or air and linear distance between interferometric fringes. Under the present method, the difference between successive interferometric fringes is of high significance, Investigations show that the separation between successive interference fringes depends on the refractive index of liquid and refractive index of lens.

4.2 THEORY:

From the general equation (3.8) from chapter III, the refractive index of test lens is given by -

$$n = \frac{n_j D_j - n_i D_i}{D_j - D_i} \qquad \text{... [4.1]}$$

Where,

n = Refractive index of test lens.

n_j = Refractive of the j^{th} medium.

D_j = Separation between successive fringes in j^{th} medium.

n_i = Refractive index of i^{th} medium.

D_i= Separation between successive fringes in i^{th} medium.

Rewrite the equation (4.1) we get -

$$n\,(D_j - D_i) = n_j D_j - n_i D_i$$

$$n_j D_j = n\,(D_j - D_i) + n_i D_i$$

$$n_j = \frac{1}{D_j} n\,(D_j - D_i) + n_i D_i \qquad \text{... [4.2]}$$

4.2.1 FORMULA FOR THE REFRACTIVE INDEX OF AIR

If j^{th} medium is air and i^{th} medium is any liquid (like Water, Xylol, Benzol etc.) then the equation (4.2) becomes as.

j = Air (a)

i = Liquid (L)

$$n_a = \frac{1}{D_a} n\,(D_a - D_L) + n_L D_L \qquad \text{... [4.3]}$$

Where,

n_a = Calculated refractive index of air

D_a = Separation between successive fringes in air.

n = Refractive index of lens immersed in liquid.

n_L = Refractive index of liquid.

D_L = Separation between successive fringes in liquid.

4.2.2 FORMULA FOR THE REFRACTIVE INDEX OF LIQUID

If i^{th} medium is air and j^{th} medium is any liquid (like water, xylol, Benzol etc.) then the equation (4.2) becomes as.

j = Air (a) and i = Liquid (L)

$$n_L = \frac{1}{D_L} n\,(D_L - D_a) + n_a D_a \qquad \text{... [4.4]}$$

Where,

n_L = Calculated refractive index of liquid.

D_L = Separation between successive fringes in test liquid.

n = Refractive index of lens immersed in test liquid.

n_a = Refractive index of air.

D_a= Separation between successive fringes in air.

4.3 OPTICAL CONFIGURATION AND PROCEDURE:

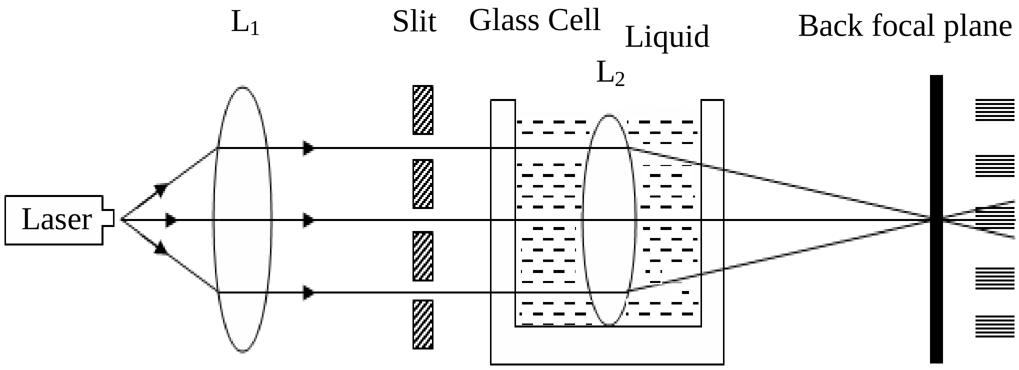

Figure 4.1: Optical configuration used for evaluating the refractive index of Air and Liquid

The optical arrangement shown in figure (4.1) consists of a glass cell filled with test liquid. The lens L_2 is immersed in liquid inside the glass cell which is placed on the optical bench in such a way that the parallel light after passing from lens L_1 and slit s, insides into the glass cell. This parallel light after passing lens L_2 and medium filled in glass cell is produce an interference pattern in to the back focal plant of lens L_2. For each investigation, new liquid is poured in to the glass cell and owing to that every time the equispaced, parallel straight fringe pattern is shifted to new focal plane corresponding to new liquid. The optical configuration and procedure is similar to the procedure describe in chapter III, because this chapter is an extended peace of work of previous chapter.

4.4 OBSERVATIONS:

Wavelength of the light used λ = 632.8 nm

Focal length of the lens

Immersed in test liquid F = 199.05 mm

Radius of curvature of lens R = 102.915 mm

Room temperature T = 24°C

4.5 RESULTS AND DISCUSSION:

Table 4.1: Calculated Refractive Index of Liquid and Air

S.No.	Medium	Separation between successive fringes in medium D(mm)	Standard Refractive index of medium	Calculated Refractive index of medium
1.	Air	1.5650	1.0000	1.0000
2.	Water	4.2440	1.3311	1.3311
3.	Xylol	25.7556	1.4927	1.4927

4.	Benzol	32.2240	1.4991	1.4991

Determination the Refractive Index of Water

If i^{th} medium is air and j^{th} medium is water then the formula used -

$$n_w = \frac{1}{D_w} n (D_w - D_a) + n_a D_a$$

Where,

n_w = Calculated refractive index of test liquid as water

D_w = Separation between successive fringes in test liquid as water

n = Refractive index of lens immersed in test liquid

n_a = Refractive index of air

D_a = Separation between successive fringes in air

Table 4.2: Calculated Refractive Index of Water

S. No.	Separation between successive fringes in water D_w (mm) (J=water)	Average value of D_w (mm)	Separation between successive fringes in air D_a(mm) (i=air)	Average value of D_a(mm)	Refractive index of lens immersed in Liquid = n	Refractive index of air = n_a	Calculated Refractive index of j^{th} liquid water = n_w
1.	4.2441	4.2440	1.5650	1.5650	1.5245	1.0000	1.3311
2.	4.2439	4.2440	1.5651	1.5650	1.5245	1.0000	1.3311
3.	4.2440	4.2440	1.5649	1.5650	1.5245	1.0000	1.3311

Determination the Refractive Index of Xylol

If i^{th} medium is air and j^{th} medium is xylol then the formula used -

$$n_x = \frac{1}{D_x} n (D_x - D_a) + n_a D_a$$

Where,

n_x = Calculated refractive index of test liquid as xylol

D_x = Separation between successive fringes in test liquid as xylol

n = Refractive index of lens immersed in test liquid

n_a = Refractive index of air

D_a = Separation between successive fringes in air

Table 4.3: Calculated Refractive Index of Xylol

S. No.	Separation between successive fringes in Xylol D_x (mm) (J=Xylol)	Average value of D_x (mm)	Separation between successive fringes in air D_a (mm) (i=air)	Average value of D_a(mm)	Refractive index of lens immersed in liquid = n	Refractive index of air = n_a	Calculated Refractive index of j^{th} liquid Xylol = n_x
1.	25.7555	25.7556	1.5649	1.5650	1.5245	1.0000	1.4927
2.	25.7556	25.7556	1.5650	1.5650	1.5245	1.0000	1.4927
3.	25.7557	25.7556	1.5651	1.5650	1.5245	1.0000	1.4927

Determination the Refractive Index of Benzol

If i^{th} medium is air and j^{th} medium is benzol then the formula used -

$$n_B = \frac{1}{D_B} n (D_B - D_a) + n_a D_a$$

Where,

n_B = Calculated refractive index of test liquid as benzol

D_B = Separation between successive fringes in test liquid as benzol

n = Refractive index of lens immersed in test liquid

n_a= Refractive index of air

D_a= Separation between successive fringes in air

Table 4.4: Calculated Refractive Index of Benzol

S. No.	Separation between successive fringes in Benzol D_B (mm) (J=Benzol)	Average value of D_B (mm)	Separation between successive fringes in air D_a(mm) (i=air)	Average value of D_a(mm)	Refractive index of lens immersed in Liquid = n	Refractive index of air = n_a	Calculated Refractive index of j^{th} liquid Benzol = n_B
1.	32.2239	32.2240	1.5649	1.5650	1.5245	1.0000	1.4991
2.	32.2240	32.2240	1.5650	1.5650	1.5245	1.0000	1.4991
3.	32.2241	32.2240	1.5651	1.5650	1.5245	1.0000	1.4991

Determination the Refractive Index of Xylol

If i^{th} medium is water and j^{th} medium is xylol then the formula used -

$$n_x = \frac{1}{D_x} n (D_x - D_w) + n_w D_w$$

Where,

n_x = Calculated refractive index of test liquid as xylol

D_x = Separation between successive fringes in test liquid as xylol

n = Refractive index of lens immersed in test liquid.

n_w = Refractive index of water

D_w = Separation between successive fringes in water

Table 4.5: Calculated Refractive Index of Xylol

S. No.	Separation between successive fringes in Xylol D_x (mm) (J=Xylol)	Average value of D_x (mm)	Separation between successive fringes in water D_w (mm) (i=water)	Average value of D_w (mm)	Refractive index of lens immersed in test Liquid = n	Refractive index of water = n_w	Calculated Refractive index of j^{th} liquid Xylol = n_x
1.	25.7555	25.7556	4.2439	4.2440	1.5245	1.3311	1.4927
2.	25.7556	25.7556	4.2440	4.2440	1.5245	1.3311	1.4927
3.	25.7557	25.7556	4.2441	4.2440	1.5245	1.3311	1.9427

Determination the Refractive Index of Benzol

If i^{th} medium is water and j^{th} medium is benzol then the formula used-

$$n_B = \frac{1}{D_B} n (D_B - D_w) + n_w D_w$$

Where,

n_B = Calculated refractive index of test liquid as benzol

D_B = Separation between successive fringes in test liquid as benzol

n = Refractive index of lens immersed in test liquid

n_w= Refractive index of water

D_w= Separation between successive fringes in water

Table 4.6: Calculated Refractive Index of Benzol

S. No.	Separation between successive fringes in Benzol D_B (mm) (J=Benzol)	Average value of D_B (mm)	Separation between successive fringes in air D_w (mm) (i=water)	Average value of D_w(mm)	Refractive index of lens immersed in test Liquid = n	Refractive index of water = n_w	Calculated Refractive index of j^{th} liquid Benzol = n_B
1.	32.2239	32.2240	4.2439	4.2440	1.5245	1.3311	1.4991
2.	32.2240	32.2240	4.2440	4.2440	1.5245	1.3311	1.4991
3.	32.2241	32.2240	4.2441	4.2440	1.5245	1.3311	1.4991

Determination the Refractive Index of Benzol

If i^{th} medium is Xylol and j^{th} medium is benzol then the formula used-

$$n_B = \frac{1}{D_B} n (D_B - D_x) + n_x D_x$$

Where,

n_B = Calculated refractive index of test liquid as benzol

D_B = Separation between successive fringes in test liquid as benzol

n = Refractive index of lens immersed in test liquid

n_x = Refractive index of xylol

D_x = Separation between successive fringes in xylol

Table 4.7: Calculated Refractive Index of Benzol

S. No.	Separation between successive fringes in Benzol D_B (mm) (J=Benzol)	Average value of D_B (mm)	Separation between successive fringes in Xylol D_x (mm) (i=Xylol)	Average value of D_x (mm)	Refractive index of lens immersed in test Liquid = n	Refractive index of Xylol = n_x	Calculated Refractive index of j^{th} liquid Benzol = n_B
1.	32.2239	32.2240	25.7555	25.7556	1.5245	1.4927	1.4991
2.	32.2240	32.2240	25.7556	25.7556	1.5245	1.4927	1.4991
3.	32.2241	32.2240	25.7557	25.7556	1.5245	1.4927	1.4991

Table 4.8: Calculated average value of Refractive Index of Test Liquid

S.No.	Name of the test Liquid	Possible pair of Medium/Liquid		Calculated Refractive index of j^{th} liquid up to 4^{th} place decimal	Standard Refractive index of test Liquid
		i^{th} Medium	j^{th} Medium		
1.	Water	Air	Water	1.3311	1.3311
2.	Xylol	Air	Xylol	1.4927	1.4927
3.	Xylol	Water	Xylol	1.4927	1.4927
4.	Benzol	Air	Benzol	1.4991	1.4991
5.	Benzol	Water	Benzol	1.4991	1.4991
6.	Benzol	Xylol	Benzol	1.4991	1.4991

Determination the Refractive Index of Air

Formula used for determination the refractive index of air -

$$n_a = \frac{1}{D_a} n (D_a - D_L) + n_L D_L$$

Where,

n_a = Calculated refractive index of air

D_a = Separation between successive fringes in air

n = Standard Refractive index of lens immersed in test liquid

n_L = Refractive index of liquid

D_L = Separation between successive fringes in liquid

Table 4.9: Calculated Refractive Index of Air

S. No.	Medium filled in Glass Cell	Separation between successive fringes in air D_a (mm)	Separation between successive fringes in liquid D_L (mm)	Standard Refractive index of Liquid n_L	Possible pair of medium used in calculation	Calculated Refractive index of air n_a (mm) upto 4th place of Decimal
1.	Air	1.5650	-	1.0000	-	-
2.	Water	-	4.2440	1.3311	Air-water	1.0000
3.	Xylol	-	25.4556	1.4927	Air-Xylol	1.0001
4.	Benzol	-	32.2240	1.4991	Air-Benzol	1.0001

In the present chapter, we have centered our attention for determining the refractive index of liquid and air. Equation 4.3 and 4.4 gives the relation to determining the corresponding value of the refractive index of air and liquid which are correct up to forth place of the decimal. The calculated refractive index of water shown in table 4.2, and the refractive index of xylol have shown in table 4.3 and 4.5, similarly the refractive index of benzol have shown in table 4.4, 4.6 and table 4.7. The total calculated refractive index of air shown in table 4.9. Which correct up to fourth place of decimals If we plot a graph between refractive index of medium and $1/D_{medium}$ (D=separation of fringe in medium) a straight line is obtained, shown in figure 4.2, the refractive index of unknown liquid can also be calculate by using the same straight line. Thus it is concluded that this straight line from figure 4.2, may be treated as a refractometer for determining the refractive index of unknown liquid. By using this method the refractive index of an unknown liquid can be easily found and hence, a quick and accurate identification of the liquids can be made. Finally the table 4.1 and 4.8 represents the calculated average value of refractive index of liquid and air.

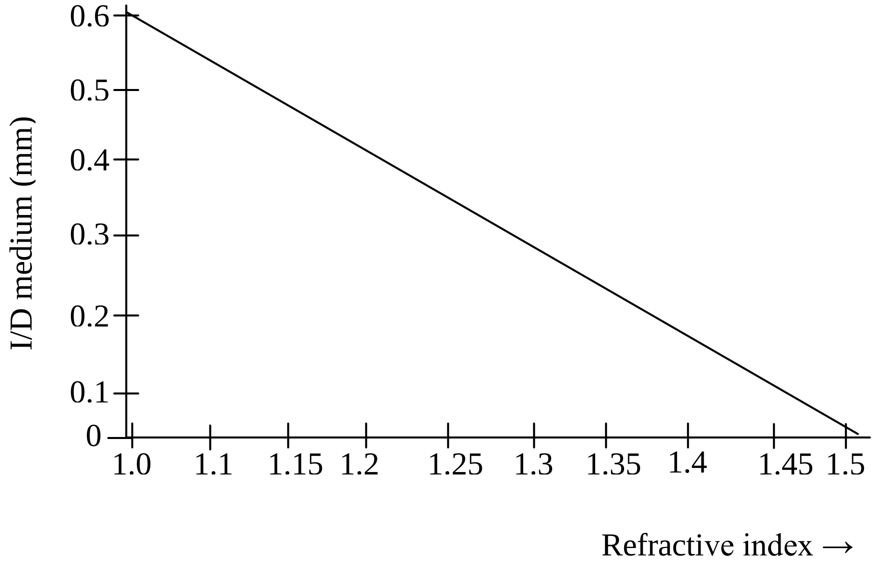

Figure 4.2: Graph between refractive index of medium and 1/ Fringe separation

Table 4.10 Separation inverse of Fringes

S.No.	Medium	Separation between fringes in medium D_{medium} (mm)	$1/D_{medium}$	Refractive index of medium
1.	Air	1.4650	0.64	1.000
2.	Water	4.2240	0.24	1.3311
3.	Xylol	25.7556	0.038	1.4927
4.	Benzol	32.2440	0.031	1.4991

4.6 CONCLUSION:

The refractive index is the fundamental properties of material, which is responsible to the internal properties like purity of materials. In the proposed technique, the separation between fringes in medium (D_{medium}) is the only measured parameter. In the present technique a minimum number of components are used, so possibility of error in refractive index calculation may be reduced. This method is very easy to get optical configuration, economic and quick to identify the refractive index of air and liquid. By using this technique we can be easily found the refractive index of unknown liquid. But some limitations are associated with this method; these are. (a) The refractive index of i^{th} medium must be less than the refractive index of j^{th} medium. (b) Some possible pair of medium is permitted for the calculation of the refractive index of text medium.

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