## 3.1 INTRODUCTION:

This chapter reports a non-destructive non-miscible liquid immersion technique with three-beam interferometry for determining the refractive index of lens material. Earlier workers have used a mixture of liquid for matching the values of lens index with the refractive index of liquid mixture, thus this value $n_L$ of liquid mixture is just equal with lens Index. In this chapter, the techniques of Kasana and Rosenbruch (1-3) for determining the refractive index of lens material have been modified. The proposed method needs only a single pair of liquid at a time. Thus, the possibility of changing the refractive index of mixture due to a slight difference in their quantities is eliminated. With two beam interference method, it is difficult to measure the position of fringe.

The Three-beam Zernike's Interferometer is easy to set up and is very stable. It has been used to calibrate phase-retardation plates as well as to measure very small changes in the optical thickness of a specimen [Vittoz, B-1956] [4]. However, because the beams are obtained by the wave-front division, the amplitudes of the individual beam are not uniform over the field. As a result, if the three beam are produced by amplitude division and produce on interference pattern consisting at equispaced, parallel straight fringe.

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The use of liquid mixture for determination the refractive index of lens has certain limitations and restriction which as are follows-

- Liquid which constituents the mixture must be a miscible in nature.
- The matching point at the refractive index of lens and the mixture is a tedious task.
- Most of the miscible organic liquids are poisonous in nature.

To eliminate such difficulties Smith (5) has come forward by using only one liquid at a time. Kasana and Rosenbruch (3) have reported a new focusing non-miscible liquid immersion technique. They have measured the refractive index of a lens as well as of liquids up to the fourth place of decimal. Richerzhagen (6) has described a simple method for measuring the absolute refractive index of liquid with Michelson interferometer. Recently several ways have been reported for finding-out the refractive indices of liquid namely grating coupled surface plasmon (7), Acousto-optic diffraction techniques by Kasana *et al.*(8), Interferometric techniques by Musso *et al.* (9) and Kasana *et al.* (10), A new technique by H. EL Ghandoor *et al.* (11) using capillary tube has been developed for finding the refractive index of crude oils. Many attempts have been make from time to time which have been reported in literature (12-23). Recently several scientists (24-30) have centered their attention on discovering the various interferometric techniques for finding the refractive index of optical materials. Luiz Poffo *et al.* (31) have described a technique for determination the refractive index of a glass using acoustic optic effect. I. G. Palchikova *et al.* (32) have proposed a new diffraction interferometry for studying the refractive index dynamics. Rajeev Gupta *et al.* (33) have suggested a method for measurement of ultraviolet index of refraction using Fourier transform spectrometer. J. Gomez Rivas *et al.* (34) have discussed the strongly scattering media for determination of the refractive index. Lijuan Su *et al.* (35) have brought forward the refractive index variation in compression molding of precision glass optical components. M. Mosarraf Hossain *et al.* (36) have brought forward the lens less Fourier digital holography for determining the refractive index. Ming Deng *et al.* (37) have put a new look on photonic crystal fiber based Fabry-Perot interferometer for measurement the refractive index of optical materials.

In the present technique, we can determine the refractive index of lens without destroying any part of it. We have centered our attention to study the refractometry of lens in present chapter. For this purpose an innovative approach has been exercised to establish a relation between refractive indices of lens and Interforometric fringe.

## 3.2 THEORY:

The separation between two successive equispaced, parallel, straight fringer, D can be written as.

$$D = \frac{\lambda}{d}.F \qquad \text{... [3.1]}$$

Where,

$\lambda$ = Wavelength of incident light.

F= Effective focal length of lens and liquid combination.

d = Distance between slit

$$\frac{\lambda}{d} = \text{Constant} = K$$

$$D = K.F$$

$$F = \frac{d}{k}$$

$$\frac{1}{F} = \frac{K}{d} \qquad \text{... [3.2]}$$

However, the focal length of the lens inside the liquid is given by

$$\frac{1}{F} = (n - n_L)(C_1 - C_2) + (n - n_L)^2.t\, C_1 C_2 / n \qquad \text{... [3.3]}$$

Where,

F = Focal length of lens

t = Thickness of the lens

n = Refractive index of the lens

$n_L$ = Refractive index of the liquid

$C_1$ and $C_2$ = Curvatures of the lens surfaces

By considering either a thin lens or Plano convex lens, the equation 3.3 is given by

$$\frac{1}{F} = (n - n_L)(C_1 - C_2) \quad \text{...[3.4]}$$

For $i^{th}$ and $j^{th}$ liquids which is filled in glass cell the equation (3.4) given as

$$\frac{1}{F_i} = (n - n_i)(C_1 - C_2) \quad \text{...[3.5]}$$

$$\frac{1}{F_j} = (n - n_j)(C_1 - C_2) \quad \text{... [3.6]}$$

By using equation (3.2), (3.5) and (3.6), we get.

$$\frac{(n - n_i)}{(n - n_j)} = \frac{D_j}{D_i} \quad \text{... [3.7]}$$

$$n\,D_j - n_j\,D_j = n\,D_i - n_j\,D_i$$

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

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

$$\mathbf{n} = \frac{n_j D_j - n_i D_i}{D_j - D_i} \quad \text{... [3.8]}$$

The equation (3.8) is called the general equation for determining the refractive index of test lens. For the pair of Air and Water equation (3.8) becomes as

$$n = \frac{n_w D_w - n_a D_a}{D_w - D_a} \quad \text{... [3.9]}$$

Similarly

For the pair of Air and Xylol, the general formula becomes as -

$$n = \frac{n_x D_x - n_a D_a}{D_x - D_a} \quad \text{... [3.10]}$$

For pair of Water and Xylol, the general formula becomes as -

$$n = \frac{n_x D_x - n_w D_w}{D_x - D_w} \quad \text{... [3.11]}$$

For the pair of Xylol and Benzol, the general formula becomes as -

$$n = \frac{n_B D_B - n_x D_x}{D_B - D_x} \quad \text{... [3.12]}$$

For the pair of Air and Benzol, The general formula becomes as -

$$n = \frac{n_B D_B - n_a D_a}{D_B - D_a} \quad \text{... [3.13]}$$

The abbreviation used in above formula is listed below

| | | |
|---|---|---|
| a | = | Air |
| w | = | Water |
| X | = | Xylol |
| B | = | Benzol |
| n | = | Refractive index of test lens (calculated) |

## 3.3 OPTICAL CONFIGURATION AND PROCEDURE:

The optical system consists of a Laser as a light source, slit and glass cell filled with liquid. The test lens 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 the slit insides in the glass cell. The optical arrangement has been shown in figure (3.1). All the components have been named in figure 3.1 itself. This parallel light after passing through the test lens and liquid, produce an interference pattern. The interference fringe pattern consisting of equispased, parallel straight fringes to back focal plane of test lens.

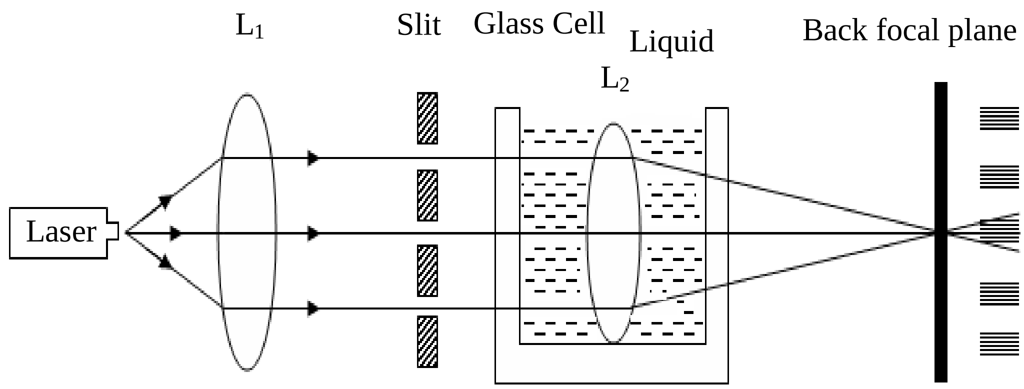


**Figure 3.1: Optical configuration used for evaluating the refractive index of test lens**

The three beam interferometer is easy to setup and very stable. For each investigation new liquid is poured in to the glass cell. Thus, every time the parallel straight fringe pattern is shifted to new focal plane corresponding to new liquid. The interference fringe, displayed in the back focal plane of the test lens can be viewed easily. The separation between successive fringes can be calculated or measured by different techniques such as, x-y recorder, photodetector as scanner, photographic recording. A traveling microscope with a photodetector and linear vernier microscope can also be used. The laser used as a light source in proposed experiment. All the investigation has been made at room temperature which is mentioned in observation title.

## 3.4 OBSERVATION:

| | |
|---|---|
| Wavelength of the light used | $\lambda$ = 632.8 nm |
| Focal length of the lens | F = 199.05 mm |
| Radius of curvature | R = 102.915 mm |
| Room temperature | T = 24°C |

## 3.5 RESULTS AND DISCUSSION:

**Table 3.1: The measurement of separation between interferometric fringes in medium of air**

| S. No. | Media | Separation between two successive fringes | | $1/D_a$ (mm) | Refractive index of media $n_a$ (Standard value) |
|---|---|---|---|---|---|
| | | $D_a$ (mm) | Average value of $D_a$ (mm} | | |
| 1. | Air | 1.5650 | 1.5650 | 0.6389776 | 1.0000 |
| 2. | Air | 1.5651 | 1.5650 | 0.6389776 | 1.0000 |
| 3. | Air | 1.5649 | 1.5650 | 0.6389776 | 1.0000 |

**Table 3.2: The measurement of separation between interferometric fringes in medium of water**

| S. No. | Media | Separation between two successive fringes | | $1/D_w$ (mm) | Refractive index of media $n_w$ (Standard value) |
|---|---|---|---|---|---|
| | | $D_w$ (mm) | Average value of $D_w$ (mm) | | |
| 1. | Water | 4.2441 | 4.2440 | 0.2356268 | 1.3311 |
| 2. | Water | 4.2439 | 4.2440 | 0.2356268 | 1.3311 |
| 3. | Water | 4.2440 | 4.2440 | 0.2356268 | 1.3311 |

**Table 3.3: The measurement of separation between interferometric fringes in medium of Xylol**

| S. No. | Media | Separation between two successive fringes | | 1/$D_X$ (mm) | Refractive index of media $n_X$ (Standard value) |
|---|---|---|---|---|---|
| | | $D_X$ (mm) | Average value of $D_X$ (mm) | | |
| 1. | Xylol | 25.7556 | 25.7556 | 0.0388265 | 1.4927 |
| 2. | Xylol | 25.7555 | 25.7556 | 0.0388265 | 1.4927 |
| 3. | Xylol | 25.7557 | 25.7556 | 0.0388265 | 1.4927 |

**Table 3.4: The measurement of separation between interferometric fringes in medium of Benzol**

| S. No. | Media | Separation between two successive fringes | | 1/$D_B$ (mm) | Refractive index of media $n_B$ (Standard value) |
|---|---|---|---|---|---|
| | | $D_B$ (mm) | Average value of $D_B$ (mm) | | |
| 1. | Benzol | 32.2241 | 32.2240 | 0.0310328 | 1.4991 |
| 2. | Benzol | 32.2239 | 32.2240 | 0.0310328 | 1.4991 |
| 3. | Benzol | 32.2240 | 32.2240 | 0.0310328 | 1.4991 |

By taking $i^{th}$ liquid = Air

And $j^{th}$ liquid = Water

Then, the formula used for calculation of refractive index of lens is given by

$$n = \frac{n_w D_w - n_a D_a}{D_w - D_a}$$

Where,

n = Calculated refractive index of test lens

$n_a$ = Refractive index of air

$n_w$ = Refractive index of water

$D_a$ = Separation between successive fringes in the medium of air

$D_w$ = Separation between successive fringes in the medium of water

**Table 3.5: Calculated Refractive index of Test lens for the pair of air and water**

| S. No. | Media | Separation between successive fringes in media = D (mm) | $D_w$ - $D_a$ (mm) | Refractive index of Medium | Calculated refractive index of the test lens = n |
|---|---|---|---|---|---|
| 1. | Air | 1.5650 | 2.679 | 1.0000 | 1.5245 |
| 2. | Water | 4.2440 | 2.679 | 1.3311 | 1.5245 |

By taking the $i^{th}$ liquid = Water

And $j^{th}$ liquid = Xylol

Then, the formula used for calculation of refractive index of lens is given by

$$n = \frac{n_x D_x - n_w D_w}{D_x - D_w}$$

Where,

n = Calculated refractive index of test lens

$n_x$ = Refractive index of xylol

$D_x$ = Separation between successive fringes in the medium of xylol

$n_w$ = Refractive index of water

$D_w$ = Separation between successive fringes in the medium of water

**Table 3.6: Calculated Refractive index of Test lens for the Pair of Water and Xylol**

| S. No. | Media | Separation between successive fringes in media = D (mm) | $D_x$ - $D_w$ (mm) | Refractive index of Medium | Calculated refractive index of the test lens = n |
|---|---|---|---|---|---|
| 1. | Water | 4.2440 | 21.5116 | 1.3311 | 1.5245 |
| 2. | Xylol | 25.7556 | 21.5116 | 1.4927 | 1.5245 |

By taking the i$^{th}$ liquid = Xylol

and j$^{th}$ liquid = Benzol

Then, the formula used for calculation of refractive index of lens is given by

$$n = \frac{n_B D_B - n_x D_x}{D_B - D_x}$$

Where,

n = Calculated refractive index of test lens.

$n_B$ = Refractive index of benzol

$D_B$ = Separation between successive fringes in the medium of benzol

$n_x$ = Refractive index of xylol

$D_x$ = Separation between successive fringes in the medium of xylol

**Table 3.7: Calculated Refractive index of Test lens for Pair of Xylol and Benzol**

| S. No. | Media | Separation between successive fringes in media = D (mm) | $D_B$ - $D_x$ (mm) | Refractive index of Medium | Calculated refractive index of the test lens = n |
|---|---|---|---|---|---|
| 1. | Xylol | 25.7556 | 6.4684 | 1.4927 | 1.5245 |
| 2. | Benzol | 32.2240 | 6.4684 | 1.4991 | 1.5245 |

By taking the $i^{th}$ liquid = Air

and $j^{th}$ liquid = Xylol

Then, the formula used for calculation of refractive index of lens is given by

$$n = \frac{n_x D_x - n_a D_a}{D_x - D_a}$$

Where,

n = Calculated refractive index of test lens

$n_x$ = Refractive index of xylol

$D_x$ = Separation between successive fringes in the medium of xylol

$n_a$ = Refractive index of air

$D_a$ = Separation between successive fringes in the medium of air

**Table 3.8: Calculated Refractive index of Test lens for Pair of Air and Xylol**

| S. No. | Media | Separation between successive fringes in media = D (mm) | $D_x$ - $D_a$ (mm) | Refractive index of Medium | Calculated refractive index of the test lens = n |
|---|---|---|---|---|---|
| 1. | Air | 1.5650 | 24.1906 | 1.0000 | 1.5244 |
| 2. | Xylol | 25.7556 | 24.1906 | 1.4927 | 1.5244 |

By taking the $i^{th}$ liquid = Air

and $j^{th}$ liquid = Benzol

Then, the Formula used for calculation of refractive index of lens is given by

$$n = \frac{n_B D_B - n_a D_a}{D_B - D_a}$$

Where,

n = Calculated refractive index of test lens

$n_B$ = Refractive index of benzol

$D_B$ = Separation between successive fringes in the medium of benzol

$n_a$ = Refractive index of air

$D_a$ = Separation between successive fringes in the medium of air

**Table 3.9: Calculated Refractive index of Test lens for Pair of Water and Benzol**

| S. No. | Media | Separation between successive fringes in media = D (mm) | $D_B$ - $D_a$ (mm) | Refractive index of Medium | Calculated refractive index of the test lens = n |
|---|---|---|---|---|---|
| 1. | Air | 1.5650 | 30.659 | 1.0000 | 1.5245 |
| 2. | Benzol | 32.2240 | 30.659 | 1.4991 | 1.5245 |

By taking the $i^{th}$ liquid = Water

and $j^{th}$ liquid = Benzol

Then, the Formula used for calculation of refractive index of lens is given by

$$n = \frac{n_B D_B - n_w D_w}{D_B - D_w}$$

Where,

n = Refractive index of test lens.

$n_B$ = Refractive index of Benzol

$D_B$ = Separation between successive fringes in the medium of Benzol

$n_x$ = Refractive index of water

$D_x$ = Separation between successive fringes in the medium of water

**Table 3.10: Calculated Refractive index of Test lens for Pair of Water and Benzol**

| S. No. | Media | Separation between successive fringes in media = D (mm) | $D_B$ - $D_w$ (mm) | Refractive index of Medium | Calculated refractive index of the test lens = n |
|---|---|---|---|---|---|
| 1. | Water | 4.2440 | 27.98 | 1.3311 | 1.5245 |
| 2. | Benzol | 32.2240 | 27.98 | 1.4991 | 1.5245 |

**Table 3.11: Calculated Average Value of Refractive index of Test lens**

| S. No. | Pair Name of Medium (Possible) | Calculated Refractive Index of Test lens, n (Up to 4th place of decimal) |
|---|---|---|
| 1. | Air - Water | 1.5245 |
| 2. | Water - Xylol | 1.5245 |
| 3. | Xylol - Benzol | 1.5245 |
| 4. | Air - Xylol | 1.5245 |
| 5. | Air - Benzol | 1.5245 |
| 6. | Water - Benzol | 1.5245 |

The position of the interference fringe has been measured using the linear traveling microscope. The He-Ne laser beam has been used as a light source. In the present chapter, we have centered our attention for determining the refractive index of lens material. Equation 3.8 gives the relation for determining the refractive index of lens material. The calculated refractive index of test lens is shown in table 3.5 - 3.10 corresponding to different combination of liquid pairs. From the above discussion we found that the calculated refractive index of lens is always correct up to forth place of decimal with each pair of liquids. It is also observed that the refractive index of $j^{th}$ liquid must be grater then the refractive index of $i^{th}$ liquid. By using general equation 3.8 we found that the average value of refractive index of test lens is n= 1.5245. The graph shown in figure (3.2) indicates variation in $1/D_{medium}$ with respect to refractive index of liquid $n_{Liquid}$. The straight line is observed which confirms the validity of general equation 3.8 and the refractive index of unknown liquid can also be calculate by using the same straight line. With this analysis it is obvious that the simple, economic, quick, easy to setup and accurate technique has been reported in this chapter. Finally the table 3.11 shows the calculated refractive index of test lens corresponding to the pair of medium. The calculated refractive index is correct up to fourth place of decimals.

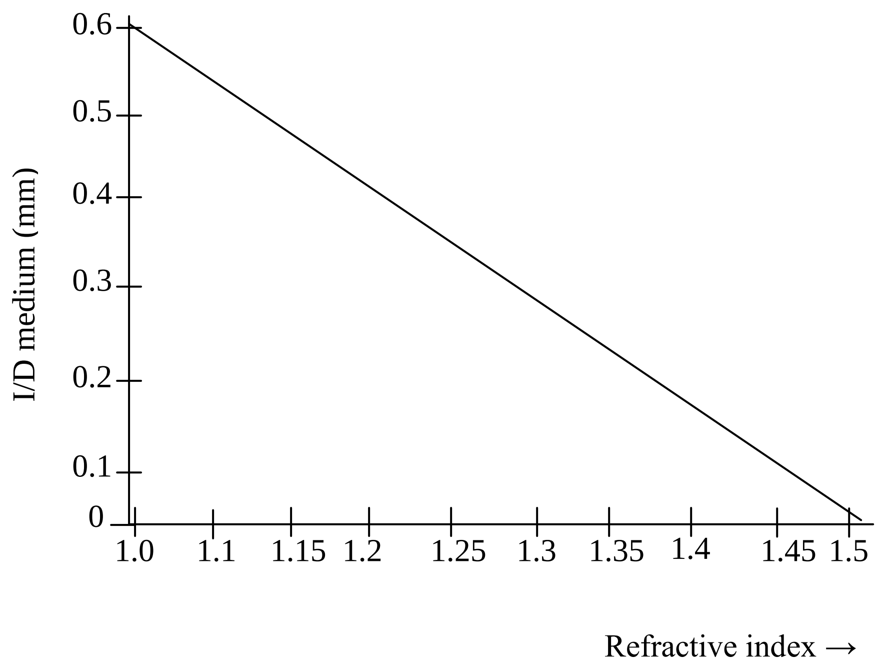


**Figure 3.2: Graph between refractive index of medium and 1/D medium**

## 3.6 CONCLUSION:

In the proposed technique the separation between successive fringes is only measured parameter. This technique is independent from wavelength of light source, focal length of lens etc., so it is clear that the error in calculation of index is also reduced. It is also concluded that the straight line from figure (3.2) may be treated as a refractometer for determining the refractive index of unknown liquid and calculated refractive index of lens material also correct up to fourth place of decimal. But it is observed that the determination of refractive index of test lens, some possible pairs of the medium are permitted. From the general equation 3.8 it is clear that the refractive index of $j^{th}$ liquid/medium must be greater than the refractive index of the $i^{th}$ liquid/medium. The above limitations are associated with this method.

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