Refractometry of Liquid by Using Liquid Immersion and Three Beam Interferometric Techniques

R. S. Kasana* and Arvind Kumar Deshmukh*

*Department of Physics & Electronics,
School of Mathematical and Physical Science,
Dr. Hari Singh Gour Central University, Sagar, (M.P.) India – 470003
Email: arvindkumar1278@gmail.com

Abstract

The refractive index is the fundamental property of material, which is responsible for the internal property of material. A technique for determining the refractive index of liquid has been reported in this paper, the proposed method is superior to the existing ones because of its significant role in glass industries, optical and chemical engineering, refractometry etc. we have centred our attention to study of the interferometric refractometry of liquid. For this purpose an innovative approach has been exercised to establish a relation between refractive index of liquid and fringe separation. The proposed method needs a pair of two separate liquid at a time. The method of liquid immersion and three beam interferometry has been adopted for evaluating the refractometry of liquids.

Keywords: Refractometry, fringe, liquid, liquid immersion, interferometry.

Introduction

The paper presents a method for evaluating the refractive index of liquid, which is based on interference phenomenon of monochromatic light. To the best of our knowledge proposed method has been used to first time for evaluating the refractive index of liquid. Kasana et al (1983 - 84) (1-3) method of liquid immersion has been adopted for this purpose. Due to importance of refractive index in chemical engineering, optical engineering and glass industries etc, it provides the scale of purity and reproducibility of optical materials. The determination of the refractive index continues to pay the ways to scientists owing to its importance in physical and chemical characteristics of a liquid. Many workers have centred their attention to discover the experimental techniques for determining the refractive index of
materials. In the proposed method for determining the index of liquid, the lens $L_2$ immersed in the liquid inside a glass cell which is placed on the optical bench in such a way that the light passing after the slit, inside the glass cell containing the test liquid. This parallel light after passing through the lens $L_2$ and test liquid produce an interference phenomenon consisting of equal-spaced, parallel and straight firings to back focal plane of lens $L_2$. If the distance between slit is minimum, it behave like a low frequency diffraction grating.

The different aspect (4-9) estimated the value of refractive index for pure liquids, can be categorized as – optical beam path variation measurement, total internal reflection, diffractometric fringe detection. Kasana et al and Rheims have reported a new liquid immersion technique [10–14] by using only a single liquid at a time for measuring the refractive index of optical material. A new technique (15) using capillary tube has been developed for finding the refractive index of crude oil. Recently some significant piece of work has been reported [16–21] for finding refractive index of liquid and lens material by using interferometer and acousto-optic diffraction technique and two beam methods.

**Theory**

The separation between two successive equal-spaced, parallel and straight fringes, $D$ can be written as.

$$\frac{1}{F} = K \frac{D}{F}$$

Where, $K = \frac{\lambda}{d}$ =constant

$D$ = Separation between successive fringe in medium
$d$ = distance between slit
$\lambda$ = Wavelength of incident light
$F$ = Effective focal length of lens and liquid combination.

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

$$\frac{1}{F} = (n - n_L)(c_1 - c_2) + (n - n_L)^2 \frac{t c_1 c_2}{n}$$

Where,

- $F$= focal length of lens
- $t$ = thickness of the lens
- $n$ = Refractive index of lens
- $n_L$ = refractive index of liquid.
- $C_1$, and $C_2$ = Curvature of the lens surfaces.

By considering either a thin lens or Plano convex lens, equation (2) is given as:

$$\frac{1}{F} = (n - n_L)(c_1 - c_2)$$

For $i^{th}$ and $j^{th}$ liquid (if we take two separate liquids says $i^{th}$ and $j^{th}$ liquid) the equation 3 becomes as-
Refractometry of Liquid by Using Liquid Immersion

\[ \frac{1}{F_i} = (n - n_i)(c_1 - c_2) \]  \hspace{1cm} (4)

\[ \frac{1}{F_j} = (n - n_j)(c_1 - c_2) \]  \hspace{1cm} (5)

By using equation (1) and (4), (5) we get

\[ \frac{n - n_i}{n - n_j} = \frac{D_j}{D_i} \]

\[ n = \frac{n_j d_j - n_i D_i}{D_j - D_i} \]  \hspace{1cm} (6)

\[ n_j = \frac{1}{D_j} n(D_j - D_i) + n_i D_i \]  \hspace{1cm} (7)

If \( i^{th} \) medium is air or any liquid (like – Air, Water, and Xylol) and \( j^{th} \) medium is any liquid (like – Distilled Water, Xylol, and Benzol etc) the equation (7) becomes as

\[ n_{j^{th} \text{ liquid}} = \frac{1}{D_{j^{th} \text{ liquid}}} n(D_{j^{th} \text{ liquid}} - D_{i^{th} \text{ medium}}) + n_{i^{th} \text{ medium}} D_{i^{th} \text{ medium}} \]  \hspace{1cm} (8)

Where,

\[ n_{j^{th} \text{ liquid}} = \text{Calculated refractive index of } j^{th} \text{ liquid.} \]

\[ D_{j^{th} \text{ liquid}} = \text{Separation between successive fringes in } j^{th} \text{ test liquid.} \]

\[ n = \text{Refractive index of lens immersed in test liquid.} \]

\[ D_{i^{th} \text{ liquid}} = \text{Separation between successive fringes in } i^{th} \text{ liquid or medium.} \]

\[ n_{i^{th} \text{ liquid}} = \text{Refractive index of } i^{th} \text{ liquid or medium.} \]

**Optical Configuration Procedure**

The optical arrangement shown in figure 1, consists of a glass cell filled with a liquid of unknown refractive index. The lens \( L_2 \) is immersed in liquid inside the cell which is placed on the optical bench in such a way that the parallel light passing from the lens \( L_1 \) and slit \( s \), inside into the glass cell, produce an interference pattern to the back focal plane of lens \( L_2 \). For each investigation, new liquid is poured in to the glass cell and owing to that every time the equal spaced, parallel straight fringe pattern is shifted to new focal plane corresponding to new liquid.

![Figure 1: Optical configuration used for evaluating the refractive index liquid.](image-url)
Observations

Wavelength of the light used \( \lambda = 632.8 \text{ nm} \)
Effective focal length of lens immersed in liquid \( F = 199.05 \text{ mm} \)
Refractive index of lens L2, immersed in liquid \( n = 1.5245 \)
Room temperature \( T = 24^\circ \text{C} \)

Result and Discussion

Table 1: The Average value of fringe separation corresponding to medium.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of medium or liquid</th>
<th>Average value of separation between successive fringe in medium ( D_{\text{medium}} ) (mm)</th>
<th>( 1/D_{\text{medium}} ) (mm)</th>
<th>Standard Refractive Index of medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air</td>
<td>1.5650</td>
<td>0.64</td>
<td>1.0000</td>
</tr>
<tr>
<td>2</td>
<td>Water</td>
<td>4.2440</td>
<td>0.24</td>
<td>1.3311</td>
</tr>
<tr>
<td>3</td>
<td>Xylol</td>
<td>25.7556</td>
<td>0.038</td>
<td>1.4927</td>
</tr>
<tr>
<td>4</td>
<td>Benzol</td>
<td>32.2240</td>
<td>0.031</td>
<td>1.4991</td>
</tr>
</tbody>
</table>

Table 2: Calculated Refractive index of a \( j^{\text{th}} \) test liquid.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of test liquid</th>
<th>Possible pairs of liquids/medium ( i^{\text{th}}<em>{\text{medium}} ) ( j^{\text{th}}</em>{\text{medium}} )</th>
<th>Calculated Refractive index of ( j^{\text{th}} ) medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>Air ( i^{\text{th}}<em>{\text{medium}} ) Water ( j^{\text{th}}</em>{\text{medium}} )</td>
<td>1.3311</td>
</tr>
<tr>
<td>2</td>
<td>Xylol</td>
<td>Air ( i^{\text{th}}<em>{\text{medium}} ) Xylol ( j^{\text{th}}</em>{\text{medium}} )</td>
<td>1.4927</td>
</tr>
<tr>
<td>3</td>
<td>Xylol</td>
<td>Water ( i^{\text{th}}<em>{\text{medium}} ) Xylol ( j^{\text{th}}</em>{\text{medium}} )</td>
<td>1.4927</td>
</tr>
<tr>
<td>4</td>
<td>Benzol</td>
<td>Air ( i^{\text{th}}<em>{\text{medium}} ) Benzol ( j^{\text{th}}</em>{\text{medium}} )</td>
<td>1.4991</td>
</tr>
<tr>
<td>5</td>
<td>Benzol</td>
<td>Water ( i^{\text{th}}<em>{\text{medium}} ) Benzol ( j^{\text{th}}</em>{\text{medium}} )</td>
<td>1.4991</td>
</tr>
<tr>
<td>6</td>
<td>Benzol</td>
<td>Xylol ( i^{\text{th}}<em>{\text{medium}} ) Benzol ( j^{\text{th}}</em>{\text{medium}} )</td>
<td>1.4991</td>
</tr>
</tbody>
</table>

Equation (8) gives a relation to determine the refractive of test liquid (\( j^{\text{th}} \)). If we plot a graph between calculated refractive index of medium and \( 1/\text{Fringe separation in medium} \), a straight line is obtained which is shown in figure 2. The refractive index of the unknown liquid can also be identifying by using the same straight line. Thus it is concluded that, this straight line may be treated as a refractometer.
Refractometry of Liquid by Using Liquid Immersion

Conclusion
The refractive index is the fundamental properties of a material, which is responsible for the internal properties like purity of materials. In the proposed technique, the separation between fringes in medium is the only measured parameter. In the present technique a minimum number of components are used, so possibility of error in calculation is also reduced. This method is very easy to get optical configuration, economic and quick to identity the refractive index of air and liquid.

References