5.1 INTRODUCTION:

In common with any optical system, an optical fibre has the property of being able to transfer light between two points. An optical fiber system can posses certain characteristics with distinguish it from a more conventional system, these are flexibility, High beam angles, the splitting and combining of light beam, alteration of the cross-section of light beam, increased transmission of the overall system, reduction in the physical size of the system. Most of the physical parameters are can be sensed by using fibers, these are, displacement, light intensity, pressure, temperature, strain, sound, rotation, magnetic field, electric field, liquid level, radiation, flow, chemical composition, variation of refractive index, pH, acoustic, current and voltage, concentration and refractive index etc.

The refractive index is the optical constant and characteristics of a material that can help to determine the impurity in material. Determination of refractive index can be contributed to find the concentration of minerals in drinking water or any other liquid as well. The refractive index has been also employed in the study of identification of organic compounds and molecular structure, in

1. **Arvind Kumar Deshmukh** and R.S. Kasana "Study the variation of refractive index of fluid with temperature by using Y-guide fiber optic refractometer', *International Journal of Computer and Engineering*, Vol.1, Issue 1, p.25-28 (2010).

2. R.S. Kasana and **Arvind Kumar Deshmukh** "Fiber optic interferometric refractometer for the study of variation of refractive index of sodium chloride wityh concentration", *International Journal of Physical Sciences, Ultra Science*, 22(1), 19-24 (2010).

manufacture control of certain product such as sugar, fats wine and beer, alcohol, alkalies, varnishes, glycerin, biological material and mineral water etc. It is important to know that the concentration of material in water and other's liquid from health point of view.

The fiber optic intensity based refractometer are well suited for wide spread industrial use because of their simplicity of design and low cost. The Intensity based refractometers are generally associated with physical perturbation like displacement of the fiber. The reduction in intensity of light is associated with microbending or absorption, scattering or fluorescence, transmission, reflection and refraction etc. The fiber optic refractometer is also used as a intensity based sensing applications. The fiber optic refractometer or sensor for measurement of refractive index can be classified in to two general classes. The first class includes the refractometer using a fiber directly immersed in the liquid under the investigations. The second class of refractometer used two optical fiber aligned on the same axis and separated by a certain distance called the Y-Guide applications.

The measurement of fluid concentration is of great interest to science and engineering disciplines. Several type of fiber based refractometer has been designed (1-13) for measurements of refractive index and its variation with concentration; many types of refractometer have been invented for simultaneous measurement of temperature effect on the refractive index (14-21). In this chapter, a simple, low cost and very efficient fiber optic interferometric and intensity based refractometer has been proposed for study of the variation in refractive index with concentration and temperature. The principle of fiber optic Y-Guide lever displacement refractometer is applied (22-24). A. C. Defranzo *et al.* (25) have measured the refractive index at low temperature. S. M. Chernov *et al.* and L. A. Danish (26-27) have reported the use of continuous liquid level sensor for measure wide range of refractive index. Kasana *et al.* (28-31) have determined the refractive index of liquids and lens by using interferometric techniques and acousto-optic diffraction techniques.

Recently some fiber based optical facility for determination of refractive index has been reported in literature. Y Jung *et al.* (32) have discussed the tree segment multimode fiber modal interferometer for refractive index measurements. Hamza *et al.* (33) have suggested the interferometric determination of refractive index by using highly oriented fibers. Ping Lu *et al.* (34) have brought forward the tapered fiber based March-Zehnder interferometer for simultaneous measurement of refractive index with temperature. Jan Jasny *et al.* (35) have been examined the method of wave length and temperature dependent measurement of refractive index. The laser and optical fiber based determination of refractive index of lens and liquid has been reported in literature (36-40). The method for the dependence of refractive index with concentration and temperature (41) has been proposed by Rioboo *et al.*.

5.2 THEORY:

The intensity of interferometric fringes is especially attractive for refractometry applications. The proposed refractometer consist of Y-Guide called fiber optic probe, plano parallel glass plate, light source as a Laser, Photodiode detector, Digital multimeter and Temperature controller cell etc. The Y-Guide is consists of two well-polished multimode fibers cemented together along some distance over the length. The transmitting guide is connected with the laser source and the receiving guide is connected to the photodiode detector and digital multimeter. The Y-Guide probe is held perpendicular to a glass plate, the transmitting guide transmits light to target and after the multiple refraction of light from the target collected by the receiving guide and transmits to a detector.

Consider a thick Plano parallel plate, whose refractive index is n_1, thickness is d and the lower side at the glass plate polished by silver materials having some refractive index n_2, on which as shown in the figure 5.1, a plane wave of unit amplitude is incident. If n_o is the refractive index of the surrounding medium, then the amplitude of the waves reflected from two surface of the plate are, for near normal incidence is

$r_1 = n_0 - n_1 / n_0 + n_1$ ... [1]

And $r_2 = n_1 - n_2 / n_1 + n_2$ ... [2]

We assume that $n_0 < n_1 < n_2$, both the waves undergo phase shift π on reflection, and the phase difference between them at normal incidence is

$$\phi = 4\pi n_1 d/\lambda \quad ...[3]$$

Then the net refracted intensity of interference pattern is

$$I(\phi) = r_1^2 + r_2^2 + 2r_1r_2\cos\phi \quad ... [4]$$

The intensity of the interferometric fringe depends on the distance of the target and fiber optic probe. Then the total intensity of the light I_{Total} at the receiving fiber is given by -

$$I_{Total} = I(\phi)\ K.R.\ \exp[-A\ (2.P)]\ f\ (p, X, n_o, NA) \quad ...[5]$$

Where I (ϕ) is the intensity of fringes, K represents the losses in the fiber system, R is the reflection coefficient, n_0 is the refractive index of sample, A is the absorption coefficient per unit distance in the medium between the fibers and target, p is the distance between fiber probe and target, X is the distance between the fibers, NA is the numerical aperture of the fiber and f (p, X, n_0, NA) is a function depending on the diameter.

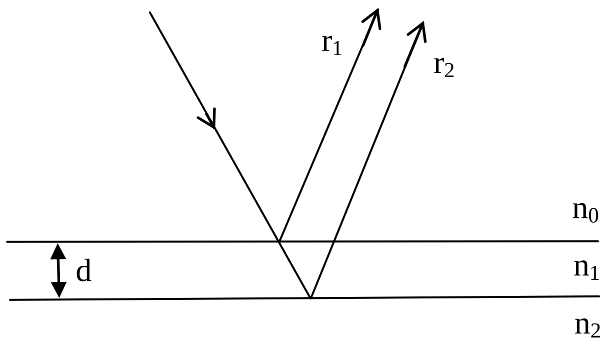

Figure 5.1 reflection of light in Plano parallel glass plate

5.3 OPTICAL CONFIGURATION AND PROCEDURE:

A Schematic optical configuration of the Y-Guide probe interferometric refractometer for the measurement of variation in refractive index with concentration and temperature is shown in figure 5.2. The experimental set-up consists of a laser, fiber optic probe as a Y-Guide, refractive surface thick plano parallel glass plate or thin films, temperature controller cell and photodiode detector or photo transistor detector (Semens SFH - 350 V.) The phototransistor SFH-350 V have following features, no. fiber stripping required, plastic connector housing, safe handling, no cross talk, most important feature of photo transistor is large operating temperature range -55°C to 100°C. The Y-Guide consists of two about 50 cm long multimode fiber's having diameter ≈ 1mm, numerical aperture 0.5, core refractive index 1.400, The horizontal and vertical displacement of the probe is achieved by micro displacement meter, which is rigidly attached to a vibration free table.

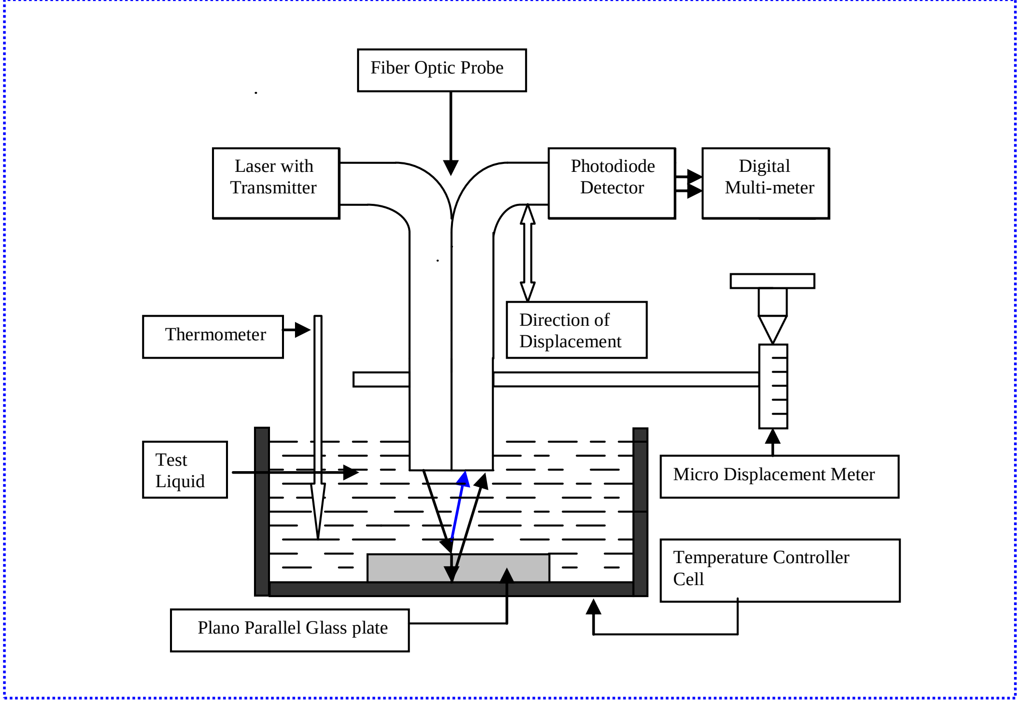

Figure 5.2: Schematic experimental set-up of the Y-Guide refractometer

The Y-Guide probe is immersed into the measuring liquid and laser is coupled into the transmitting fiber. The signal from the receiving guide is measured with moving the probe away from the zero point, where upper surface of the glass plate and probe are in close contact. Detector received the signal from receiving probe and converted to it in voltage which is measured by digital multi-meter. The total experiment completed into two separate procedures, first for the study of variation in refractive, index with concentration and second is the study of variation in refractive index with temperature.

(A) Procedure for the study of variation of refractive index with concentration: The probe is first immersed into the test liquid as distilled water and the intensity of receiving light after the multiple refraction in glass plate, is measured by changing the position of the fiber optic probe. The measurement is carried out for the solution of glucose concentration 10%, 20%, 30%, 40% and 50% in distilled water.

The experiment is repeated for the different concentration of glycerol and sodium chloride at the constant temperature 28°C. The refractive indexes are measured and compare the result by another refractometer.

(B) Procedure for the study of variation in refractive index with temperature: The probe is first immersed in distilled water at constant temperature 30°C and measured the intensity at fringe pattern. The measurement are carried Out for various temperature of test liquid as 40°C, 50°C, 60°C and 70°C. The experiment repeated for the glycerol and vegetable oil.

5.4 RESULTS AND DISCUSSION:

Figure (5.3 to 5.5) shows the variation of displacement corresponding to peak intensity with refractive index of glycerol, glucose and sodium chloride concentration in distilled water. From the figure it is seen that the higher value of the refractive index occurs peak intensity of receiving light at large distance. It is also observed that, there is a linear relationship between signals received by receiving fiber and refractive index of test liquid. From the above discussion it is concluded that, as the concentration of a test liquid increases the refractive index of test liquid proportionally.

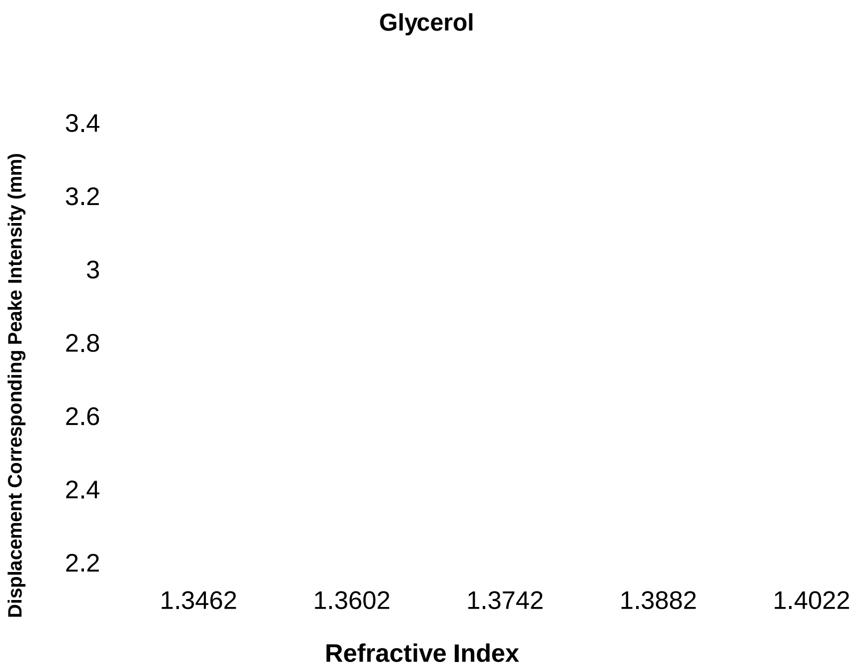

Figure 5.3: Displacement corresponding to peak intensity with refractive index of glycerol at various concentrations in distilled water.

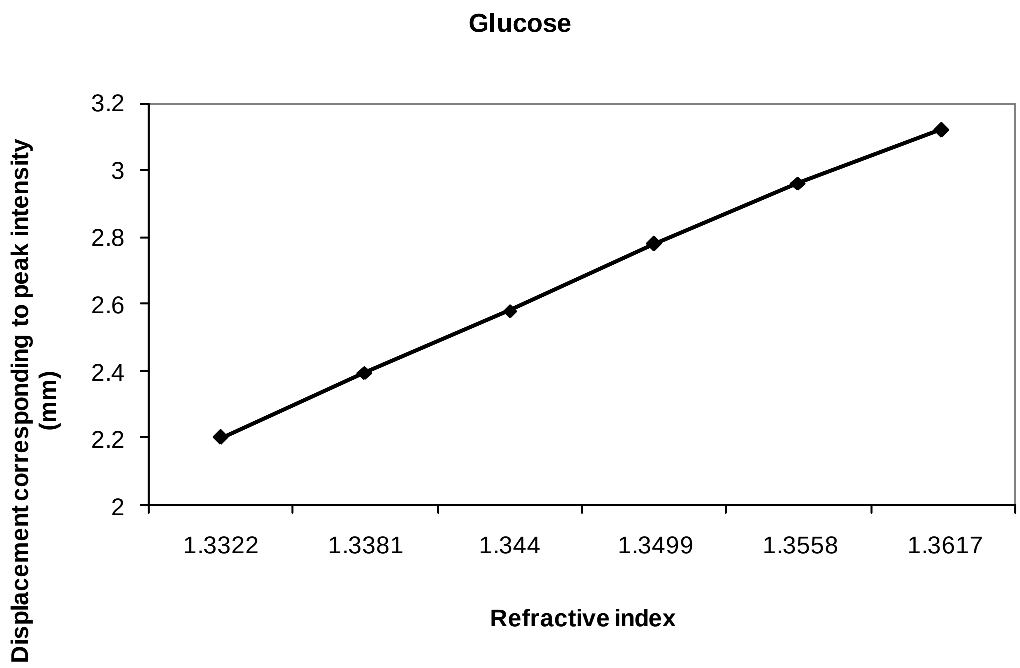

Figure 5.4: Displacement corresponding to peak intensity with refractive index of glucose at various concentrations in distilled water.

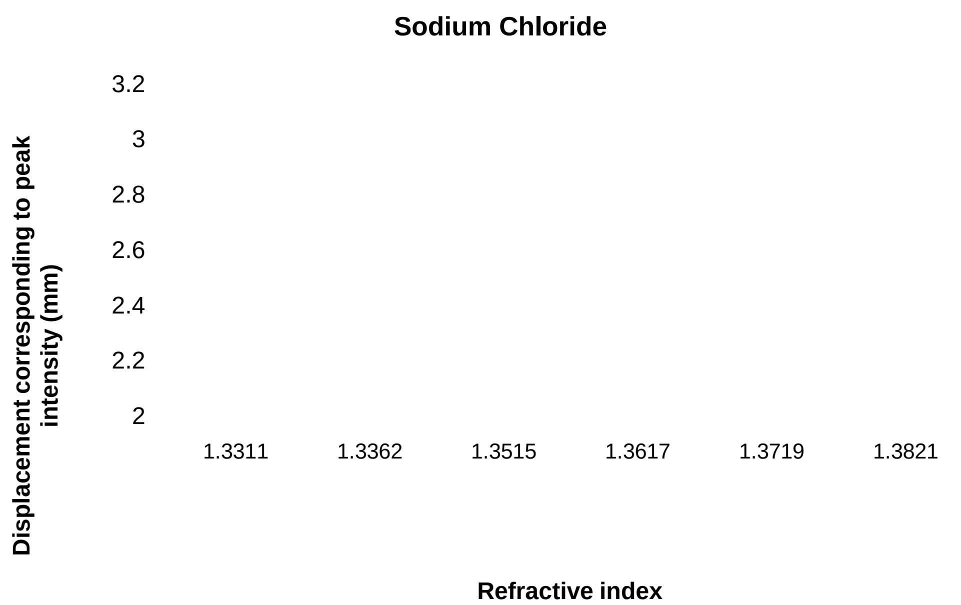

Figure 5.5: Displacement corresponding to peak intensity with refractive index of sodium chloride at various concentrations in distilled water

Figure 5.6-5.8 shows the displacement corresponding to peak intensity with various concentration of glycerol, glucose and sodium chloride in distilled water

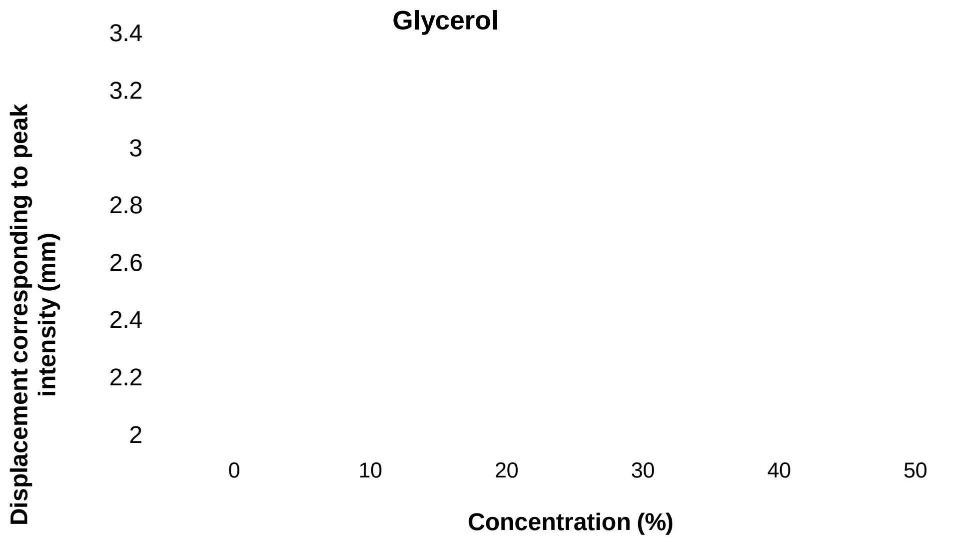

Figure 5.6: Displacement corresponding to peak intensity with various concentration of glycerol

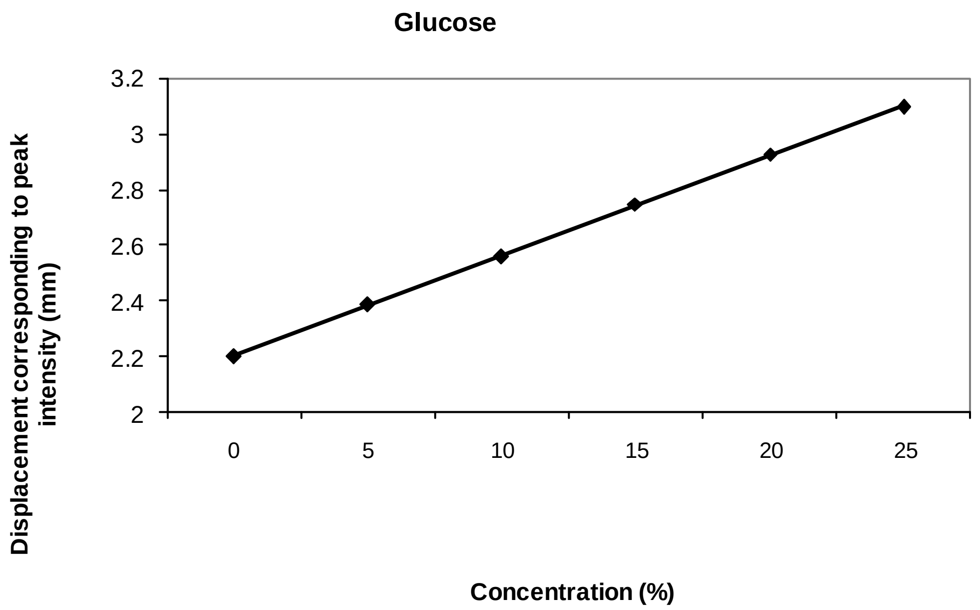

Figure 5.7: Displacement corresponding to peak intensity with various concentration of Glucose

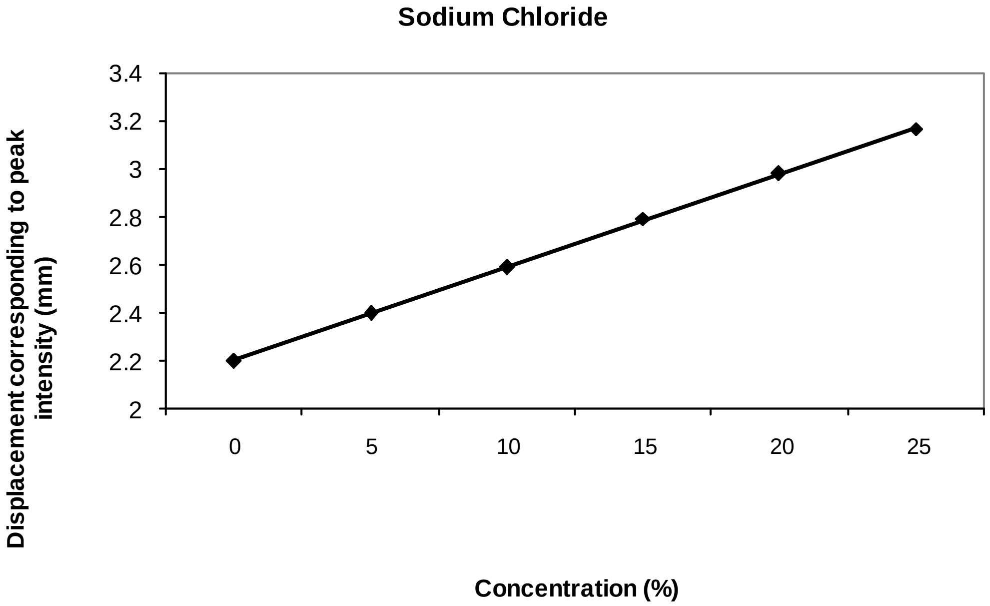

Figure 5.8: Displacement corresponding to peak intensity with various concentration of Sodium Chloride

Figure 5.9-5.11 shows the variation of peak voltage with various concentrations of glycerol, glucose and sodium chloride.

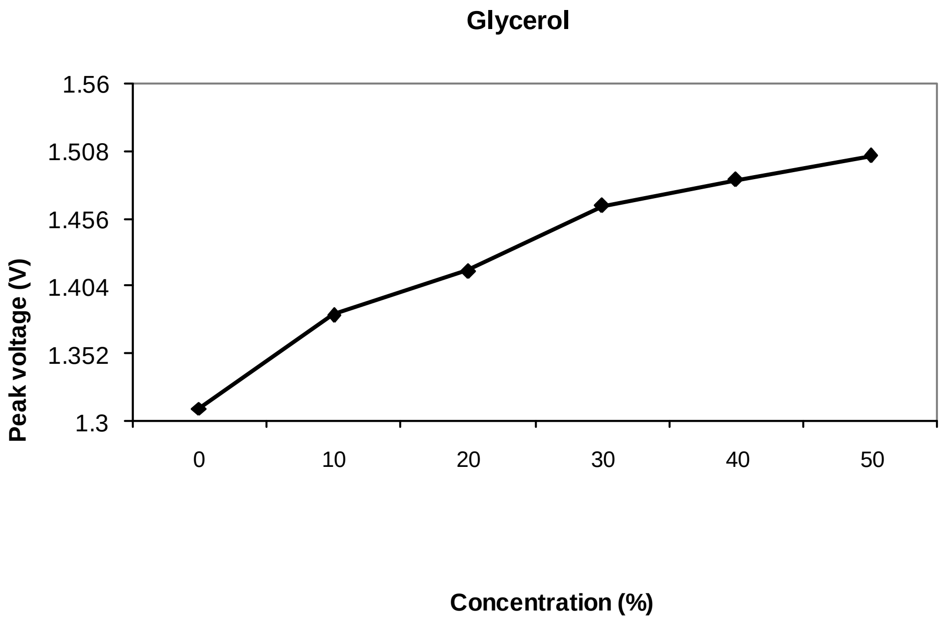

Figure 5.9: Variation of peak voltage with various concentration of glycerol

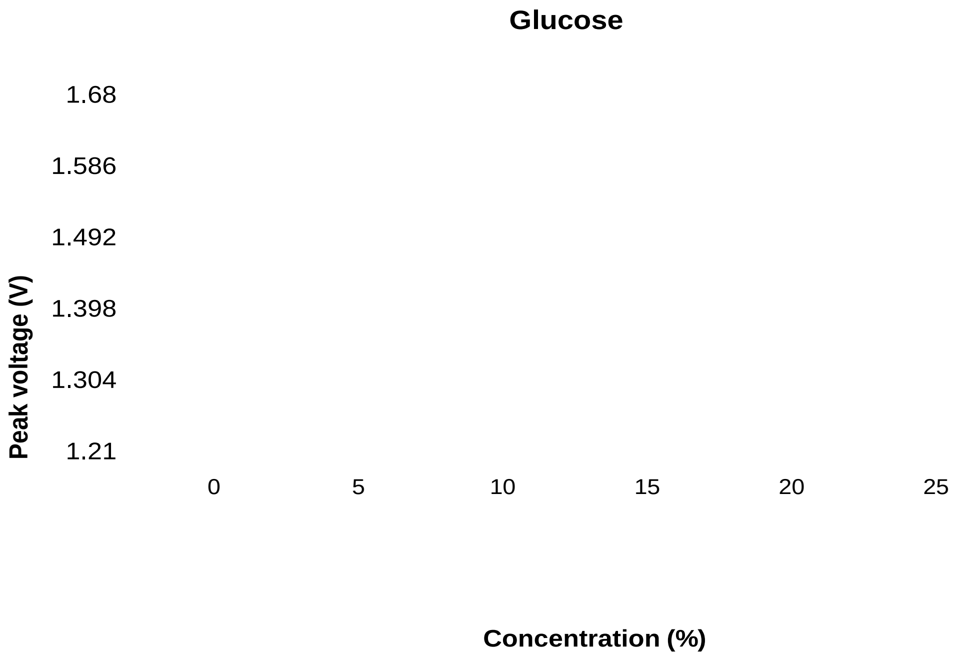

Figure 5.10: Variation of peak voltage with increasing concentration of glucose.

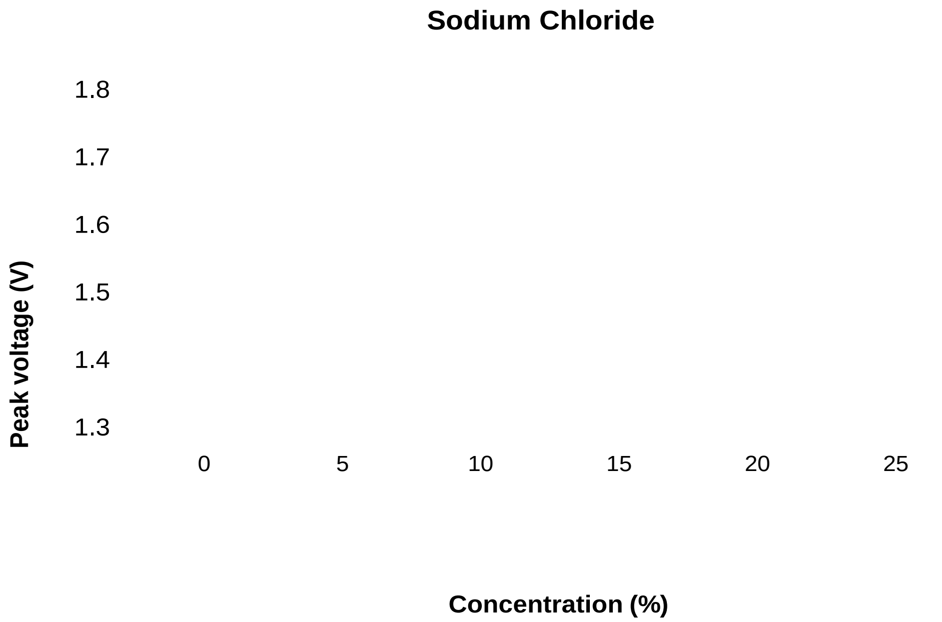

Figure 5.11: Variation of peak voltage with increasing concentration of sodium chloride.

For the variation in refractive index with temperature figure 5.12 -5.14 shows the variation of the displacement corresponding to peak intensity with refractive index of distilled water, glycerol and vegetable oil. From the figure it is observed that, at higher value of refractive index, the peak intensity occurs at maximum distance of probe from target. The results show that there is a linear relationship between signal received by the receiving fiber and refractive index of medium. It is observed that, when the temperature increases, the displacement of probe corresponding to the peak intensity decreases. The variation of intensity is due to the change of the refractive index of test liquid, which actually changes the acceptable angles of the Y-Guide optical fiber probe.

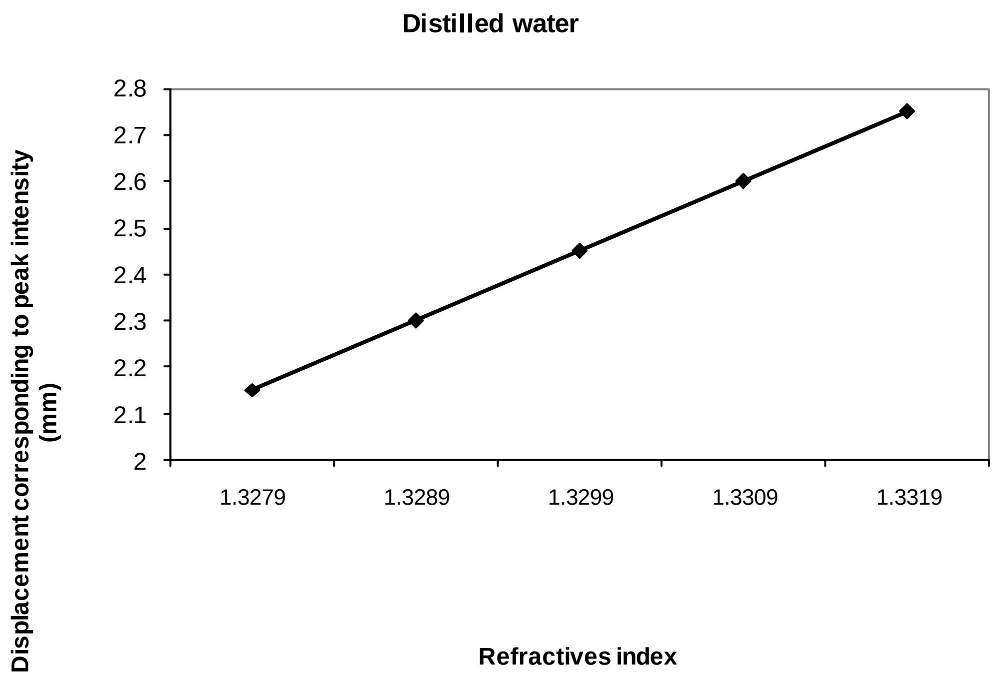

Figure 5.12: Variation of the displacement corresponding to peak intensity with refractive index of distilled water.

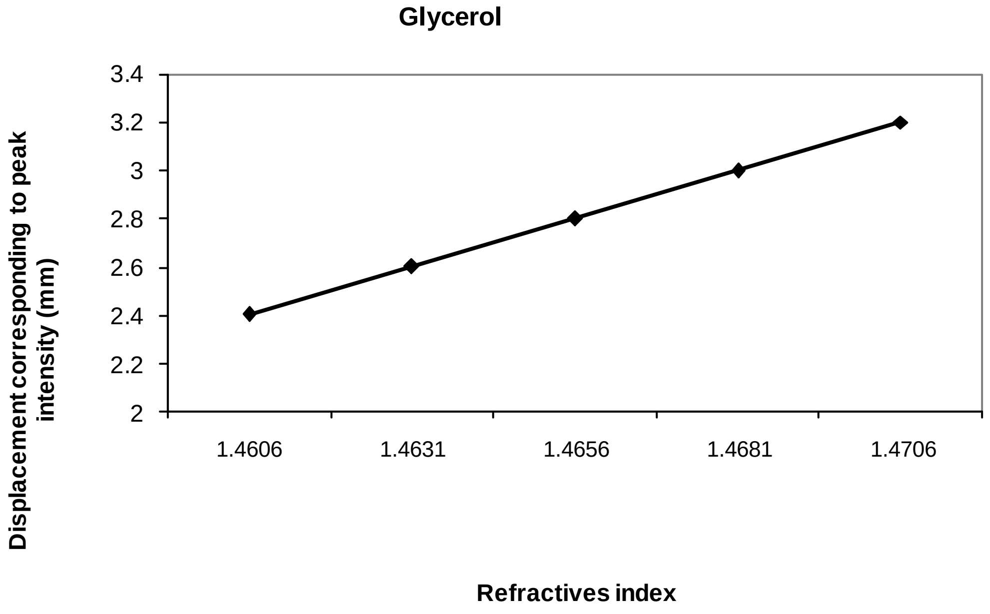

Figure 5.13: Variation of displacement corresponding to peak intensity with refractive index of glycerol.

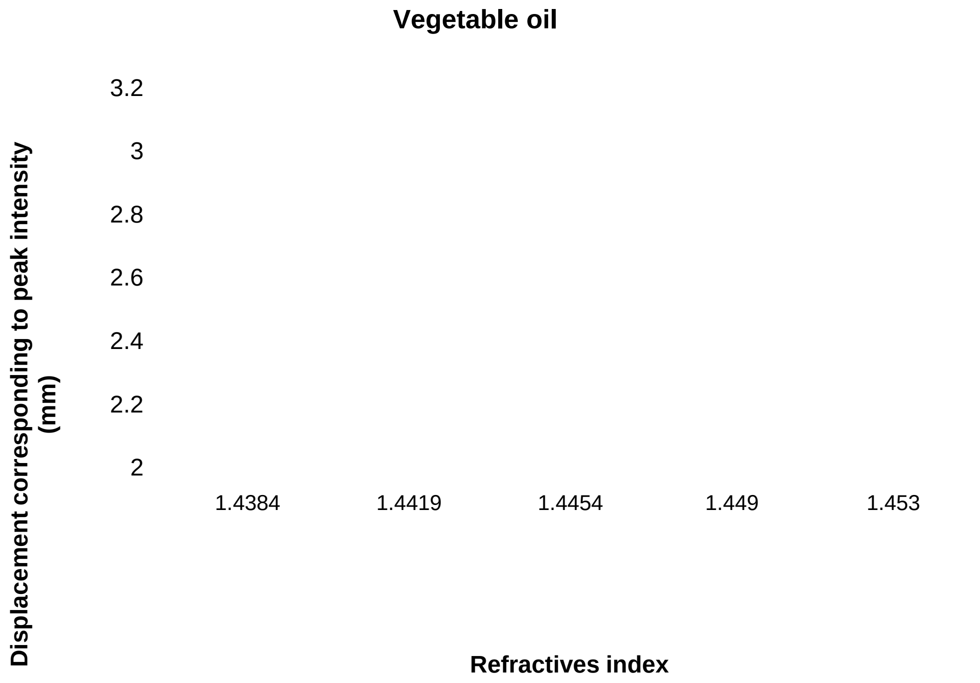

Figure 5.14: Variation of displacement corresponding to peak intensity with refractive index of Vegetable oil.

Figure 5.15 shows the variation of displacement corresponding to peak intensity with temperature of distilled water, vegetable oil and glycerol. Figure 5.16 shows the variation of peak voltage with increasing of temperature of distilled water, vegetable oil and glycerol.

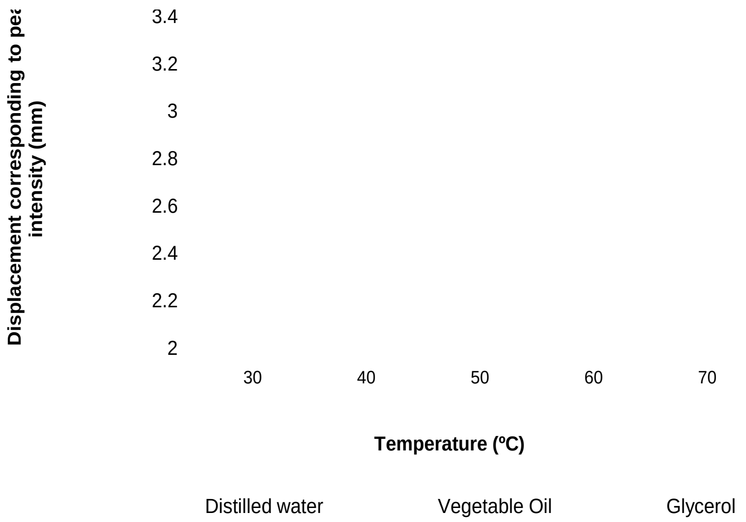

Figure 5.15 Variation of displacement corresponding to peak intensity with temperature of distilled water, Vegetable oil and glycerol.

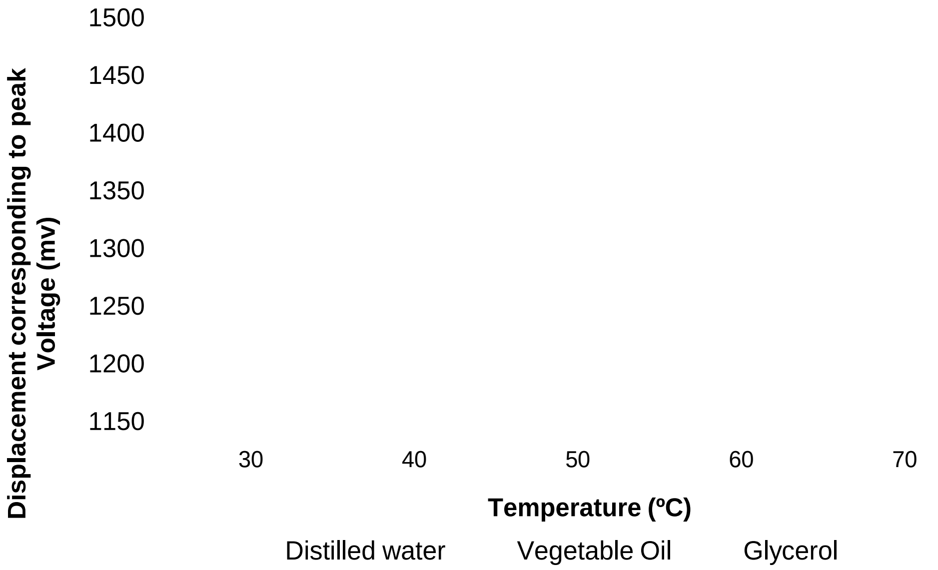

Figure 1.16: Variation of peak voltage with temperature of distilled water, vegetable oil, and glycerol.

From the results it is concluded that as the temperature of test liquid increases, the refractive index of test liquid is decreases. The intensity of the refracted light varies according to the motion of Y-guide, thus providing a signal proportional to the displacement. The error due to launch conditions and due to displacement of Y-guide is estimated to negligible.

The source of error in refractometer operation can be due to stray light, mechanical vibrations and temperature. Following precautions are taken for reduce the effects of mentioned circumstances. A well regulated power supply is used, the vibration free table used for experimental set-up. Other environmental parameters like atmospheric pressure, humidity, sound does not have any effects on the proposed experiment.

5.5 CONCLUSION:

The unique advantages of the proposed interferometric refractometer are, the refractometer can be used to measuring the variation in refractive index with concentration and temperature and it can be used to assess the purity of sample by comparing the value of refractive index of pure liquid. The proposed refractometer used to identify of a sample by comparing its refractive index to known value. A conclusion can be drawn that, this proposed refractometer may be used to control the refractivity of liquids.

Some limitations of this method are - (a) The I_{total} is a real and complex quantity so the formula verification is the subject of future research work. (b) Only variation of refractive index of material can be determined by this method.

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